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RESEARCH AND DEVELOPMENT STRATEGIES FOR EMBEDDED TRAINING

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13. ABSTRACT (Maximum 200 words)

Embedded training (ET) is a training capability designed into or added onto operational equipment. Military training managers are giving ET increased attention. This study assesses how much the Air Force will use embedded training and whether the Air Force Human Resources Laboratory (AFHRL) could develop a useful and important embedded training research and development (R&D) activity. The study involved learning about potential customers' problems and the Laboratory's scientific strengths vis-a-vis those of other R&D organizations. It uses the information to devise an R&D strategy for embedded training. The study recommends that, if AFHRL decides to undertake an embedded training R&D activity, it focus on three areas. One is developing ways to ensure the safety of systems with embedded training. The second is embedding job performance measures and intelligent tutors into Air Force standard computer systems. The third is developing analytic methods for considering embedded training within a total training systems approach.

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SUMMARY

Embedded training (ET) is receiving increasing attention in the world of military training. Historically, the Air Force Human Resources Laboratory (AFHRL) has devoted few resources to embedded training research and development (R&D) issues. This study was undertaken (a) to assess the extent to which embedded training will be used in the Air Force in the future, and (b) to develop an R&D strategy for embedded training. It focuses on how AFHRL could use its strengths to address the problems of potential Air Force users of embedded training R&D. In doing so, it attempts to apply private sector strategic planning methods to a military laboratory.

Embedded training is a training capability which is designed into or added onto operational equipment. During the first phase of this study, the authors reviewed the literature on embedded training and surveyed military embedded training developers and users to identify systems. They established a database of embedded training systems, from which 14 of the more promising systems were selected for further in-depth study. Air Force program managers were contacted to find out what factors determined whether training would be embedded into each system. Phase I led to three important conclusions:

1. Embedded training is found predominately in signal processing systems like radar and sonar.

2. For various reasons, embedded training is not used for maintenance training.

3. Embedded training is used predominately for continuation training.

During the second phase of the study, the authors visited four potential AFHRL customers to find out what problems they were encountering with embedded training. In addition, they assessed the capabilities of private sector firms engaged in or capable of performing embedded training research. The authors then identified technology development areas that addressed potential R&D customer needs and that built upon AFHRL's special strengths. This assessment resulted in a proposed embedded training R&D strategy for AFHRL.

The study identifies six embedded training technology development areas in which AFHRL could conduct R&D. Each area is discussed in terms of the potential customer, relevant AFHRL strengths, and risks. If AFHRL decided to go into embedded training R&D, the authors recommend that three AFHRL divisions each be given responsibility for marketing a technology development area to a specific potential customer:

Division	ET Issue	Potential Customer
AFHRL/OT	ET Safety	Aeronautical Systems Division
AFHRL/ID	Embedded Job Performance Measures and Intelligent Tutors	Standard Systems Center
AFHRL/LR	Total Training Systems	Air Force Space Commad

The authors recognize that if AFHRL chooses to develop an embedded training R&D activity, the Laboratory would have to invest significant time in acquiring the support of potential

customers for embedded training R&D. So, if the Laboratory decides to proceed, it should designate a single individual as AFHRL's embedded training advocate. This individual would be responsible for coordinating the Laboratory's embedded training R&D, serving on the Embedded Training Working Group of the Joint Services Technical Coordinating Group, and spearheading the Laboratory's marketing efforts.

PREFACE

This strategic planning study was undertaken by the Laboratory with the assistance of Air Training Command's Training Technology Applications Program under contract No. F41689-86-D-0009. This is the final report of that study, which centered around establishing a viable R&D strategy for the Laboratory in embedded training.

The project benefited from many helpful suggestions from Drs. Herbert J. Clark and Robert W. Stephenson. The authors would like to express their appreciation for Dr. Clark's and Dr. Stephenson's interest and help.

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I. INTRODUCTION

Reasons for an Embedded Training Strategic Planning Study

Several considerations have led the Air Force Human Resources Laboratory (AFHRL) to undertake an embedded training study at this time. First, weapon systems are becoming far more complex and are more likely involve computerized components. The computing power of today's weapon and support systems provides designers with an opportunity to build-in capabilities to help operators maintain their proficiency. Second, because embedded training is already being used throughout the Air Force for certain kinds of training applications, it is a natural area for AFHRL to investigate. Although embedded training is not in extensive use, it is a viable training option and particularly well suited "continuation training." Third, reductions in Defense resources may lead the Air Force to give embedded training opportunities more serious consideration. Faced with declining resources, the Air Force should examine embedded training as an option that might provide more cost-effective solutions. In a future scenario with fewer planes, fewer funds for operational deployments and sorties, fewer replacement personnel, and less initial training, embedded training could provide an attractive way for sustaining essential wartime skills.

The Army and the Navy have devoted more attention than the Air Force to embedded training. The Navy is conducting studies to determine the applicability of embedded training to various fielded and developmental systems. These include such applications as the AN/SPA-25G radar system, the MK-117 fire control system, the AN/BSY-2 combat control system, and the OJ-194 Naval Tactical Data System (MATRIS Summary Report, 1989). Several of these systems are generally similar to existing Air Force systems and demonstrate the utility of embedded training. The Army has conducted extensive research in the area of embedded training. The Army Research Institute (ARI) has produced a 10-volume report on implementing embedded training (Finley, Alderman, Peckham, & Strasel, 1988). This research has indicated the viability of embedded training as an alternative to other forms of training.

Embedded training has not been a major focus of research at AFHRL. The reasons stated above have led the Laboratory to consider it for inclusion on their research and development (R&D) agenda. The present investigation contributes to that goal in two ways: First, it assesses the extent to which embedded training will be used in the Air Force in the future; second, it devises an embedded training R&D strategy for AFHRL. The remainder of this chapter will discuss what embedded training is and will outline will outline the approach used in the study.

Definition of Embedded Training

Embedded training (ET) has been defined by the Joint Technical Coordinating Group for Training Systems and Devices (JTCG-TSD) as *a training capability which is designed into or added onto operational equipment* (Study Plan for Embedded Training, 1989). The operational equipment itself thus becomes the delivery medium for the instruction.

Embedded training can be either fully incorporated into operational software (i.e., "built-in"), or "strapped onto" the operational system. An example of a strap-on embedded training system is the F-16 On-Board Electronic Warfare Simulator (F-16 OBEWS). This system consists of

a pod that is attached to an operational aircraft to enable it to "function" in the embedded training mode. An example of a built-in system is the Airborne Operational Computer Program (AOCP) software, which is part of the Airborne Warning and Control System (AWACS) weapons direction system. The AOCP allows the operator to use the AWACS equipment in a simulation mode to practice switch actions necessary to direct aircraft to targets. In either case, the critical point is that the operator's perception of the difference between the training mode and the operational mode of the system is minimal. The training looks and feels "real."

Although the JTCG-TSD definition focuses on operational readiness, it does not rule out other types of training which might be embedded. The following sections of this chapter will identify various kinds of embedded training and describe some features of each.

Types of Embedded Training

Simulation embedded training is the prototypal form of embedded training; that is, it meets the definition to-the-letter. It is most common among computer systems dedicated to a specific application. In simulation embedded training, some form of job-related scenario is presented on the displays and/or console normally used for system operation. The F-16 OBEWS system is a typical example of this kind of embedded training. The F-16 OBEWS system allows the pilot to conduct electronic warfare exercises against single or multiple threats without other aircraft to simulate those threats. Although there are no other aircraft involved in the training scenario, the pilot sees the same displays on his sensors as he would if he were flying an actual combat mission. Frequently, systems with simulation embedded training are strategic systems such as the Ballistic Missile Early Warning System (BMEWS) or PAVE PAWS phased array radar system. The "real-world" scenarios found in these systems are frequently used to train individuals or combat teams on those procedures which they must follow during operational situations. The simulation embedded training often provides practice (in the team training environment) for improving the operator's decision making skills. The embedded training features of these systems allow the system operators to see ballistic missile threats on their sensors that they would otherwise not be capable of experiencing except in an emergency situation.

The definition of embedded training may be expanded to include more than system-specific software. Embedded training can take one of two other forms: tutorial or job aiding. In *tutorial embedded training*, screens of text, graphics, and/or questions are presented to the trainee. This form of embedded training is commonly used to provide the operator-trainees fully developed lessons on some topic related to the system's use on the job. It is particularly useful for teaching new information or skills. Tutorial embedded training differs from simulation embedded training in that it does not attempt to precisely emulate the actual job environment; tutorial embedded training emulates the classroom or study environment (i.e., it is like a computer-based training (CBT) lesson). The World Wide Military Command and Control System (WWMCCS) provides a good example of tutorial embedded training. There are tutorial lessons available on WWMCCS for a wide variety of applications. The operator-trainee can select those lessons which would be most helpful for his specific job assignment.

In *job aiding embedded training*, information is made available to the system operator as needed, in the form of help screens, glossaries, and other such utilities. Everyone who has used commercial software products which have "help" features has experienced some type of job aiding embedded training. Job aiding embedded training can be used to help new users become oriented to a system but seldom attempts to train beyond that level. Neither tutorial nor job aiding embedded training meets the highly realistic operational job practice capability of simulation embedded training.

Embedded training offers unique training advantages and disadvantages. Because it utilizes the actual operational equipment, it is usually readily available. There is no requirement for classrooms, instructors, simulators or other equipment. Most importantly, simulation embedded training allows trainees to practice with actual equipment and facilitates the transfer of skills to actual operational situations. Well-planned embedded training can also strengthen the training process in other ways, such as by providing trainee performance assessment, immediate feedback, and specific remediation geared toward the immediate job environment. On the downside, embedded training may cause additional equipment wear-and-tear and may even pose safety or security hazards.

Approach

The present effort had two goals. The Phase I goal was to assess the potential of embedded training for the future Air Force. In Phase II, the goal was to devise a viable embedded training R&D strategy for AFHRL. This phase represented an attempt to apply private sector strategic planning methods to a military laboratory. The focus of private sector strategic planning methods is on creating and sustaining a position of *competitive advantage* in the marketplace. Such planning usually involves considering the customers' needs, one's own strengths, and the strengths of competitors.

Because AFHRL is a Government research agency, not all private sector strategic planning methods are applicable to it. AFHRL is not a private sector organization which competes for business in the open marketplace. However, there are numerous analogous situations where AFHRL must "compete" for its "customers'" business; that is, it must perform R&D which other Air Force agencies or major commands are interested in and are willing to support. Like the business plans of most successful businesses, AFHRL's embedded training R&D strategy must take into account: (a) the customers' needs, whether perceived by the customer or not; (b) other organizations within the Government or in the private sector who can provide embedded training R&D (potential competitors or teammates); and, (c) AFHRL's relevant R&D capabilities.

Phase I

During the first phase of the study, the goal was to assess trends in embedded training throughout the military services. To accomplish this end, we developed a database of embedded training systems already in use or being developed by the military. We contacted selected individuals involved in embedded training at research organizations, acquisition agencies, and system development organizations. The information obtained was used to establish the database and to verify the accuracy of its contents. A literature review was conducted from which we identified approximately 68 different Air Force, Army, and Navy systems. The embedded training database includes information about each system's sponsor, platform, application, development status, configuration, and features. (Appendix A shows the kind of information contained in the database.)

Phase I also aimed to determine what considerations impacted decisions to use or not use embedded training. This issue was addressed by studying further 14 of the more promising systems. A set of selection criteria was established which took into account those items of interest to AFHRL. Most of the systems selected were Air Force systems in various stages of development or fielding. Therefore, the criteria considered that some of the systems should have entered engineering development within the last 7 years; a few of the systems must be ones to which an embedded training capacity had been added after they entered operational use; most of the systems should be Air Force or joint projects with some other service; and, a cross-section of systems should be included (e.g., communications, radar, management

information systems, command and control). The systems listed in Table 1 were selected for further study.

Table 1. **Phase I Systems Selected for Further Study***

Air Force	Army	Navy
AWACS	Patriot	ACTS
ASAS/ENSCE	TIU	SETS
ATF		
COOF		
F-16 ET		
F-16 OBEWS		
OBS F-15		
PACCITS		
TEMPLAR		
WWMCSS		

*The database contains detailed descriptions of each of these systems.

The authors interviewed the personnel responsible for each system to find out what considerations impacted their decisions to use or not use embedded training. A questionnaire was developed and used to provide some structure to the interviews (see Appendix B). Typically, a contact involved an initial phone call to gather preliminary information and establish a basis for further discussion with either the initial contact or others involved in the acquisition or development of the system. During interviews, a copy of the completed questionnaire was normally provided to the interviewee to check for accuracy and to further direct their attention to the information we felt would be of interest to AFHRL. Respondents were always allowed to deviate from the questionnaire if they had something to say about embedded training. Often these deviations resulted in fascinating anecdotal information about the system which, when coupled with data from other sources and other systems, helped to form our total impression of Air Force embedded training. Because of the small sample involved and the qualitative nature of the data, formal statistical analysis techniques were not used. Chapter II contains the results of Phase I.

Phase II

The focus of the second phase of the study was on developing a strategic plan for embedded training research at AFHRL. Developing a viable strategy requires understanding potential users' needs, assessing the competition, and building on the organization's relative strengths. The purpose is to build on an organization's strengths to meet its customers' and potential customers' needs. Therefore, in the second phase of the study, we identified potential embedded training R&D customers for AFHRL. We conducted site visits to selected Air Force organizations to determine what kind of problems Air Force users are having with embedded training. The problems were examined in light of AFHRL and its potential competitors' (i.e., private sector companies and other DoD organizations) relative strengths at solving them. After analyzing this information, we developed an embedded training R&D strategy for AFHRL.

As a starting point we used the contacts established during Phase I to identify potential embedded training customers. Air Force organizations judged to have a high likelihood of involvement in embedded training were initially contacted by phone. Visits were made to those

organizations which seemed to be the most promising candidates as potential customers. During the site visits, personnel from the following Air Force organizations were interviewed:

Aeronautical Systems Division:

Support Systems Engineering, Training Systems Division (ASD/ENET)

Training Systems SPO, Directorate of Tactical & Trainer Training (ASD/YWF)

C-17 SPO, Directorate of Test, Deployment, and Training Systems (ASD/YCT)

Electronic Systems Division:

Intelligence and C^3CM Systems, Automated Message Handling System (ESD/ICL)

Tactical Systems, Over-the-Horizon Backscatter Radar (OTH-B) (ESD/TCO)

Tactical Systems, Modular Control Equipment (MCE) (ESD/TCR)
Joint STARS Program Office (ESD/JS)

Space and Missile Warning, PAVE PAWS (ESD/SRP)

U.S. E-3 Program Office (ESD/YWP)

Air Force Space Command:

Space Operations Training and Stan/Eval (AFSPACECOM/DOT)

Training Plans Division (AFSPACECOM/XPTT)

NORAD Training (NORAD/J3T)

1013th Combat Crew Training Squadron:

Satellite Operations Training (1013 CCTS/DO)

NORAD Command Post Crew IQT (1013 CCTS/JO)

Training Equipment Maintenance (1013 CCTS/LK)

Air Force Standard Systems Center:

Cargo Movement Operation System Division (SSC/AQFT)

CAMS Program Management Office (SSC/AQMD)

Medical Systems Program Office (SSC/AQS)

Combat Ammunition System Program Office (SSC/AQWS)

Directorate of Comptroller Systems (SSC/SMC)

Directorate of Engineering and Transportation Systems (SSC/SML)

Technical Support Division (SSC/SSBT)

Professional Development Division (SSC/KST)

ATC Training Advisory Office (SSC/TTA)

Plans and Requirements Office (SSC/XP)

A questionnaire was developed to guide these interviews (see Appendix C). Our assessment of customer embedded training R&D needs will be presented in Chapter III.

Our assessment of AFHRL's relative strengths with regard to embedded training R&D is based on a review of the Laboratory's projects. We surveyed the completed or in-process projects of each AFHRL division and matched the capabilities demonstrated with those needed to perform the requisite embedded training R&D. Our assessment of AFHRL's competitors' relative strengths is based on information and opinions gathered during the course of this study from various Government representatives involved in the acquisition and development of embedded training systems. We also interviewed several industry representatives from the private sector companies represented at the 11th Interservice/Industry Training Systems Conference. There were five presentations on embedded training at the conference. We were able to discuss specific embedded training systems with the presenters. Our assessment of AFHRL's and its competitors' relative strengths appears in Chapter IV.

Our overall goal in formulating an R&D strategy for AFHRL was to identify a competitive "niche" for the Laboratory within the wide range of R&D which can be performed. Another way of looking at our approach is shown in Figure 1. That figure shows that some Air Force "customer needs" can be met by R&D. Of the "researchable" customer needs, those that are matched by AFHRL's relative strengths in R&D (shaded area in Figure 1) will be targeted by the R&D strategy which we have formulated for AFHRL. The details of the proposed AFHRL R&D strategy are discussed in Chapter V.

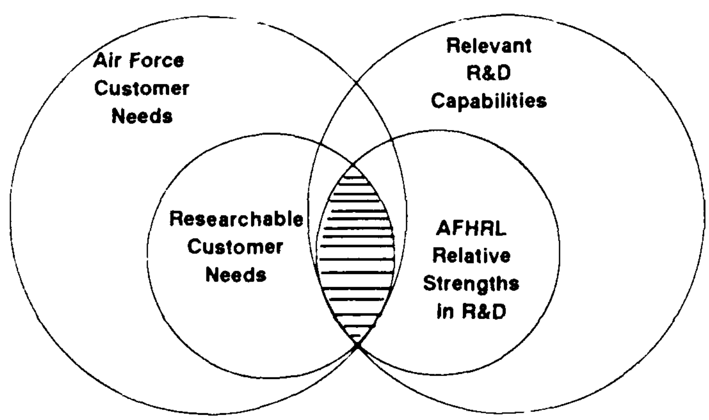


Figure 1. **AFHRL R&D Strategy.**

II. FUTURE USES OF EMBEDDED TRAINING IN THE AIR FORCE

Phase I Findings

During Phase I of the study, we analyzed the state of embedded training in the Air Force and made projections regarding future uses of embedded training. This chapter discusses the various applications of embedded training in four major areas of interest to the Air Force: embedded training in signal processing, aboard aircraft, for maintenance, and in general purpose computer systems. It also discusses how embedded training is being used to train people in the Air Force, and why it is being used the way it is.

Applications for Embedded Training

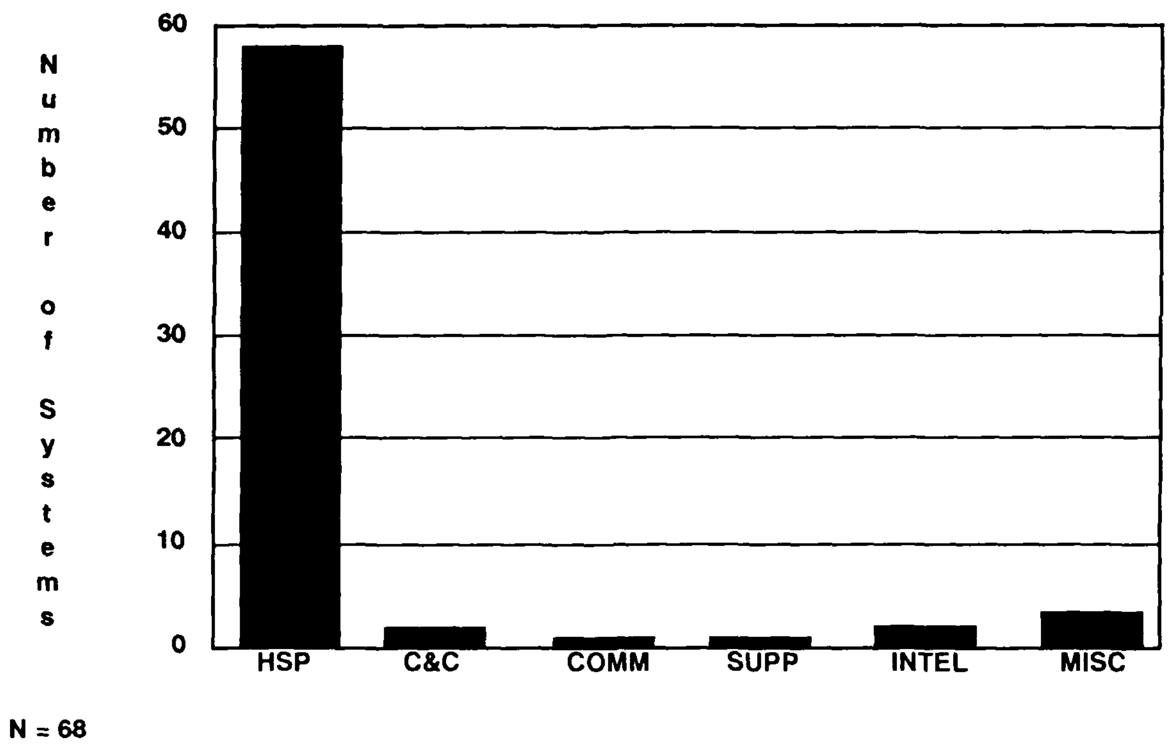
Currently, some form of embedded training (simulation, tutorial, or job aid) appears in a wide variety of computerized military systems. The precise form of the embedded training tends to vary considerably with the specific computerized application. For example, simulation embedded training tends to be used within strategic systems such as PAVE PAWS and the NORAD Command Post systems. Even some current tactical systems which started out as strategic systems have simulation embedded training capabilities (e.g., AWACS). General purpose computer support systems such as the Medical Personnel Records System (MPRS) and the Base Contracting Automated System (BCAS) tend to make use of either job aid or tutorial embedded training, or both.

The use of job aid or tutorial embedded training for support applications is not surprising in that most support applications run on general purpose computers which can accommodate a wide variety of software from training to databases, etc. However, it is far more interesting to note when and why embedded training is included in the more specialized systems, due to the fact that presumably it is more difficult to add a training capability to these systems.

Embedded Training in Signal Processing

We found that within specialized computer systems, *embedded training is most likely to be found in those systems that involve some form of signal processing*. Signal processors are systems which require a human operator to interpret and respond to some type of video or audio signal, such as radar or sonar systems. They typically involve reading signals from a scope and properly classifying these signals as threats or not. Of the 68 specialized computer systems identified in the first phase of this study, 58 (almost 90%) fell into this category (see Figure 2). Many of the Navy systems studied can be classified as signal processing systems. There was, however, a significant difference between the Air Force and the Navy when it came to the system operators. Navy shipboard-type sensor systems (usually found in a ship's combat control center) are normally tactical systems which are routinely operated by enlisted technicians. On the other hand, similar Air Force systems can be either tactical (e.g., C^2) or strategic (e.g., space warning and sensor) systems. The Air Force systems can be operated by officers or enlisted technicians. The aircraft systems studied (AWACS and F-16 OBEWS) are more frequently operated by officers. In both the Air Force and Navy cases, the embedded training capability allows the entire operational team to practice making those decisions they would be required to make under wartime or threat conditions. The other computerized systems investigated were evenly distributed across several other categories such as intelligence, communications, and command and control decision aids, etc.

Figure 2. **Applications of ET in the Military.**



HSP	-	**Human Signal Processing**	**Supp**	--	**Financial Support**
C&C	-	**Command and Control**	**Intel**	-	**Intelligence Gathering**
Comm	-	**Communications**	**Misc**	-	**Miscellaneous**

We believe that embedded training capabilities in the Air Force will continue to be found most often in signal processing systems in the future. There appear to be two reasons for this trend. First, *the technology necessary to embed a training capability into an operational system is often already available as part of these systems.* Contractors routinely build-in system test functions to help evaluate these systems prior to Government acceptance. These functions can often be used or modified for training. Indeed, respondents from those programs with an embedded training capability frequently referred to the capability as the "system test" function rather than as the embedded training function. In some cases, only after the system was fielded was it recognized that this system test function provided an excellent opportunity to train new operators and maintain the proficiency level of experienced operators.

A second reason for the trend to include an embedded training capability in signal processing systems is that the ability to recognize and respond properly to a threat is a highly critical skill which requires frequent testing and practice under emergency conditions. Pilots and radar, sonar, and electronic warfare operators need to be able to respond immediately and correctly

in threat situations. Embedded training allows operators of these systems to practice wartime procedures under simulated wartime situations; therefore, there may be a greater impetus to embed a training capability into these systems than in other types of specialized computer systems.

Embedded Training Aboard Aircraft

Embedded training is found much less frequently aboard aircraft than it is found in shipboard or ground-based systems. However, several Air Force personnel at Tactical Air Command (TAC) and the Aeronautical Systems Division (ASD) have expressed an interest in embedding training within aircraft systems. After all, aircraft do utilize signal processing systems with video and audio signals. Yet, only two airborne embedded training systems have been fielded: the F-16 OBEWS and AWACS. Three other aircraft embedded training systems (for the F-15, the F-16, and the Advanced Tactical Fighter) are currently in the planning stages; however, they have met considerable resistance from some quarters within TAC and ASD.

The resistance is due to concerns about limited on-board computer memory capacity and weight limitations. Weight limitations could constrain the addition of a pod like the F-16 OBEWS. Many aircraft acquisition personnel want to use every additional ounce to maximize the performance of the aircraft. They perceive embedded training as an unneeded extra, because other acceptable ways to address the training requirements are available. One Air Force acquisition manager has said that embedded training "weighs too much!" Whether true or not, concerns about added weight kept embedded training off aircraft.

The AWACS and F-16 OBEWS are not really exceptions to this trend. The AWACS embedded training component is not an aircraft system per se; rather, it is part of a radar system which happens to be aboard an aircraft. Similarly, the F-16 OBEWS is a pod which is attached to an F-16 for Electronic Warfare training. It can be removed quickly when the aircraft needs to be combat ready.

Embedded Training for Maintenance

Embedded training has not been used for maintenance training. After much searching, we were able to make contact with only one individual who could identify a maintenance embedded training system--the Automated Ground Engine Test System (AGETS). The embedded training component for this system turned out to be a "page-turner" tutorial which introduces the test system to new users. It does not provide training for maintenance technicians in troubleshooting problems with the system or making repairs; that is, it is *not* used for training the performance of maintenance tasks. Based on our inability to find any evidence from the literature search or through personal interviews of embedded maintenance training systems, it appears at this time that *embedded training is not being used to teach maintenance skills*. This does not imply that embedded training is incapable of being used for training maintenance skills, but that Air Force training managers and computer system designers and developers appear to have ruled it out for other reasons.

There are three possible explanations for the lack of embedded training systems for maintenance training. First, we found a widespread concern among the people we contacted about accidental insertion of faults into operational equipment while using that equipment. Second, all the Air Training Command (ATC) training managers whom we interviewed believed there was some policy that prohibited embedded maintenance training. However, we could not obtain a copy of the policy. A third reason might be that maintenance skills do not lend themselves to being taught through embedded training as easily as other skills; training such

skills as troubleshooting might require a different approach. It may well be that embedded training works best for procedural skills. This is yet to be determined by research. We are forced to conclude that, *if present trends continue, embedded training is not likely to be used to teach maintenance skills in the future.*

Embedded Training in General Purpose Computer Systems

As mentioned previously, embedded training in general purpose computer systems takes the form of tutorial or job aiding rather than simulation. This is probably due to the fact that general purpose applications do not require rehearsal, as signal processing applications do. There is not the criticality for an immediate response to a signal or threat that there is with "operational" systems. Although there may be a real need for better quality training for general purpose computer systems, it usually takes the form of a tutorial or job aid. These are considerably less expensive to develop than job simulations.

We found that embedded training was frequently planned for a general purpose system but not developed. For example, the Comptroller's Office of the Future (COOF) program originally planned to add an embedded training component to its accounting subsystem. However, during the software development process, the embedded training component was left out. As a result, instruction on the system is currently being carried out by Mobile Training Teams (MTTs) from ATC. Our interviews with an Accounting and Finance Center System 2200 program manager indicated that the embedded training component was deleted because of a lack of resources. The System 2200 software development organization also felt that the addition of embedded training would have degraded system performance.

In summary, we found that embedded training can be used within both specialized and general purpose computer systems. Within specialized systems, embedded training tends to be used most frequently within signal processing systems such as radar or sonar systems. Aircraft systems are an exception to this rule. This is probably attributable to concerns about embedded training consuming the aircraft's limited resources. In general, it is much easier to add embedded training capabilities to general purpose computer systems. However, the impetus to do so is not as great as with specialized systems. Finally, whatever the reason, embedded training tends *not* to be used for maintenance training at this time. We expect these trends in embedded training applications to continue in the future.

Use of Embedded Training

Because the embedded training capability is by definition built into *operational* equipment, it tends to be used for on-the-job training. The users of embedded training are usually qualified operators. They do not have a requirement for training new skills. *The primary use of most embedded training systems is to maintain operational readiness proficiency.* It keeps operators ready to do their jobs.

Many of the personnel interviewed for this study had never heard the term "embedded training" applied to the system capability they were using for proficiency training. They referred to it as an "exercise capability" or "simulation capability." In their minds, the term "training" applies to the schoolhouse or to initial qualification training.

The effect of an embedded training component can extend beyond the actual computerized system operator. For many signal processing systems, the embedded training capability is used not only by the operators sitting at the consoles, but also by their fellow team members involved in using the information and making decisions based on that information. In our

interviews, we found that although embedded training can be used for individual operator training, *it is most frequently used for team training exercises.* For example, NORAD Command Post exercises are used not only to train technicians to operate their consoles, but also to train commanders in the decision-making and coordination procedures that they would need to follow during actual operations. With the appropriate communications hookups, even inter-site or multi-platform training is possible. The Navy is currently making use of such communications links to extend training to multiple ships participating in limited combat control center exercises.

Finally, we noted that embedded training does not seem to fall under the rubric of formal Air Force training. We were unable to find any Air Force policy which addressed the way(s) in which embedded training should be used either on-the-job or in formal school training or how it is to fit into a total training picture. Air Training Command does not have such a policy at the headquarters level, nor could we find any policy guidance at the Technical Training Centers. Air Training Command seems to consider embedded training a system-specific capability for which the Major Commands (MAJCOMs) have responsibility.

In summary, we found that *embedded training is commonly regarded by its users as a system capability useful for operational readiness training of experienced operators and teams.* There does not appear to be any Air Force policy governing its use, employment, or development as a training medium. Decisions about its use tend to be made in the field, often at the unit level.

Development of Embedded Training

Because embedded training tends to be regarded more as a system capability than as a training medium, it is developed in a different way than are dedicated training systems. Indeed, the embedded training components of most systems are not "developed" in the sense that trainers use the term. Training system development normally involves using some form of the Instructional Systems Development (ISD) process. This frequently begins with the development of a job and task analysis, from which training requirements are derived and specifications for the system are established. Training objectives are developed along with evaluation standards and test items. Finally, the appropriate media (which would presumably include embedded training as an alternative) are recommended and selected based on cost and trade-off analyses. In contrast, embedded training systems development may range from simple enhancement of the existing system's test capability (e.g., PAVE PAWS and BMEWS) to full-blown use of the ISD process (e.g., ACTS, SETS). However, the former approach is more typical.

The developers of embedded training systems tend to have different backgrounds from those of other training system developers. Contractors which are presently developing systems with embedded training are often *not* training systems or services-oriented companies. They tend to be developers of electronics and communications systems, such as Boeing, Litton, and Raytheon. For such contractors, developing embedded training is more of an engineering task than a training development task. Within the Air Force, personnel from the user (operational) commands are frequently involved in the discussions leading up to the design of a system's embedded training capability. Air Force *training specialists* are rarely involved in the design of an embedded training capability.

Finally, unlike dedicated training systems, embedded training is not costed separately from its host system. Many of the personnel we interviewed told us that they could not give a figure for the cost of the embedded training component(s) of a system. Presumably, because the embedded training capability was considered part of the host system, there were no cost figures available. In a large-scale procurement, the embedded training capability is considered an extension of the system test capability.

In summary, the development of embedded training is handled very differently from the development of dedicated training systems. In some cases, the inclusion of embedded training *in a system is purely serendipitous. When it is purposefully included in a computerized system,* it is viewed more as a means for practice of essential skills than as a means for acquiring new skills. We have every reason to believe that this trend will continue in the future.

Embedded Training System Architectures

There are two distinct embedded training architectures. Embedded training systems may be either built into a host system ("fully embedded") or attached to the host via a separate piece of hardware ("strapped on"). Each type of embedded training has its advantages and disadvantages. For example, strap-on embedded training components are normally *added* to existing systems. This can be disadvantageous in some instances, particularly in the case of aircraft embedded training systems. Some specific objections to strap-on embedded training systems for aircraft have been voiced by Gershanoff (1989). He reports, "One argument voiced against the OBEWS pod approach is that it would not be as good as an embedded training system, where the circuits that generate threat signals and training scenarios are built into the aircraft and perhaps the operational avionics and EW gear themselves." A more realistic reason for pilots' objections to OBEWS and pods in general may be that ". . . pods of any kind are not the favorite things of pilots, who claim that they can cause asymmetric loading when mounted on one of the nine F-16 weapon stations, and that they may impair aircraft handling" (Gershanoff, 1989). Other objections to strap-ons may be that they add weight to a system, they may cause additional equipment wear-and-tear because they are repeatedly connected and disconnected, and they are themselves another piece of equipment to acquire and maintain. However, fully built-in embedded training is sometimes not the best or most convenient solution to a problem. For example, given the space and computer memory limitations in small tactical aircraft, strap-on systems like the F-16 OBEWS represent the most viable way of embedding training for the pilots of these aircraft.

Normally, one might expect a built-in to be better than a strap-on embedded training system. However, built-in systems can have disadvantages of their own. For example, our interviews showed that built-in systems often fail to capitalize on previous work in selecting the needed embedded training features (i.e., playback, performance recording, etc.). One built-in system is frequently as different from another built-in system as from a strap-on system.

In summary, we believe that both strap-on and built-in embedded training systems will continue to be used. Strap-on components will continue to be used for embedding training in existing systems. Built-in embedded training will probably be used for developing systems. We believe that *strap-on embedded training systems probably represent the wave of the future for aircraft*, because they do not consume aircraft space or resources. On the other hand, *large computerized ground-based systems will probably tend to be fully embedded (i.e., built-in)*.

Future Improvements to Embedded Training

There are several technological developments which could impact embedded training in the future. Improved speed and memory capacity, artificial intelligence programming techniques, and enhanced graphics displays could all enhance training (Massey, Harris, Downes-Martin, & Kurland, 1986).

Few institutional forces are driving the development of embedded training technology. It is not clear that users of embedded training are looking for either improved embedded training or improved technology for embedded training. As mentioned earlier, many Air Force users

of embedded training are not aware that they are using embedded training. They view the embedded training function they have not as training, but as a system capability which provides them with an inexpensive and convenient means of maintaining skill proficiency. Moreover, users are not particularly dissatisfied with the capabilities they have. They really don't know if anything better is available.

III. POTENTIAL CUSTOMERS' NEEDS

Site Visit Findings

Most of our information regarding problems which are being encountered with embedded training has come from data gathered during our visits to four separate Air Force organizations. This section summarizes what we learned about AFHRL's potential customers and the customers' perceived needs regarding embedded training. First, we will summarize our findings by organization; then we will group our findings into significant problem areas. The problems described in this section may not all have research solutions. However, our intent is to first present a full menu of problems, and then to identify those that AFHRL can potentially address.

Aeronautical Systems Division

At the start of our visit to ASD, we were told that embedded training had been proposed for the F-15, the F-16, the C-17 and the Advanced Tactical Fighter (ATF) aircraft. However, in subsequent discussions with the C-17 System Program Office (SPO), its staff said that they knew nothing about an embedded training capability.

Little embedded training information has been released regarding the ATF. We suspect that little might have been done to embed training capabilities into its operational systems. The specifications for the ATF require only that embedded training be investigated; they do not stipulate that specific training requirements be addressed by embedded training.

Of the two active aircraft (F-15 and F-16), only the F-16 has a fielded embedded training system--OBEWS. However, OBEWS is being developed by the Munitions Systems Division (MSD), rather than by ASD. The OBS F-15 (On-Board Simulator) is currently in the experimental stages; it consists of an on-board simulation capability embedded in an experimental Integrated Flight/Fire Control (IFFC) flight test program for the F-15. The ASD Plans and Programs Office's Embedded Training for Tactical Aircraft project is also in the early concept investigation stages. This ET system, which is intended to train EW skills, at this time consists of a ground simulator which is being used for pilot testing; that is, it has not yet flown.

During our interviews we found definite interest in embedded training research in some quarters at ASD. The Plans and Programs Office (ASD/XR) is presently investigating the feasibility of embedding training aboard tactical aircraft; however, ASD/XR does not appear to be a potential AFHRL customer. Individuals from the Wright Research and Development Center, Flight Dynamics Laboratory (WRDC/FIGX) and the ASD Engineering Division (ASD/ENET) have already approached AFHRL to request research assistance on embedded training using the F-15 OBS.

Not everyone at ASD is enthusiastic about embedded training. The problem seems to be that many aircraft SPO program management personnel perceive embedded training to be an added burden on the aircraft, and thus are reluctant to support it. There is a concern that embedded training will add weight to the aircraft or will consume scarce computer resources.

According to one interviewee at ASD/ENET, the following considerations are key issues in embedded training:

1. The impact of embedded training on avionics complexity.

2. The impact of embedded training on avionics reliability and maintainability.

3. Prevention of false alarms in non-training modes.

4. Potential fixation on synthetic targets (i.e., whether the synthetic targets generated by the embedded training system will cause confusion or otherwise distract attention from real targets).

5. Acceptable methods for implementing safety features.

6. Determination of the requirements of the end users of embedded training.

7. Types of real-time feedback needed.

8. Types of performance measurement needed.

The first five of these items have an impact on system safety. ASD appears to want answers in all these areas *before* it can begin to incorporate embedded training in the systems it is acquiring or developing.

According to ASD, SPO program managers need assistance in evaluating the usefulness of embedded training in current and emerging weapon systems. Currently they must default to traditional OJT or use CBT as a substitute because they cannot properly predict whether embedded training is an acceptable alternative. A legitimate area for R&D is the investigation of embedded training as an acceptable alternative for maintenance training.

Electronic Systems Division

The Electronic Systems Division (ESD) has provided an embedded training capability in at least some systems since the late 1950s. However, the individuals that we interviewed from ESD had not heard the term "embedded training" used to describe these system capabilities. Moreover, the ESD personnel we talked to generally did not perceive themselves to be developers of "training." Consequently, although ESD might benefit from embedded training research, the division must be approached using different terms (i.e., ones that they can understand and relate to).

Not all program offices were equally cognizant of the possibilities of embedding training. Users and potential users of embedded training at ESD could benefit from knowing how other electronic systems have successfully used embedded training and how the capability can be built into an operational system. For example, the embedded training within PAVE PAWS and BMEWS, two Space and Missile Warning Systems developed by ESD/SR, is a modified version of the system test capability. In contrast, the program managers working with the Over-the-Horizon Backscatter (OTH-B) Radar System told us that adding an embedded training capability to OTH-B would probably be too expensive because it was technologically too difficult. Yet, OTH-B is essentially the same type of system as PAVE PAWS and BMEWS. Why one group of program managers thought embedded training was technologically infeasible and/or too expensive while the other group included the capability in their system might reflect a lack of guidance regarding embedded training. The OTH-B program managers were not drawing on

the experience of the BMEWS or PAVE PAWS program managers. The point is that there is no embedded training guidance available now for program managers to help them make their decisions. Without the experience of similar past projects, program managers have no basis for making informed system training decisions.

Air Force Standard Systems Center

The Air Force Communications Command's Standard Systems Center (SSC) is responsible for acquiring computer systems which will be used by two or more MAJCOMs. Systems acquired by SSC generally consist of some combination of general purpose hardware and broad applications software. Many of SSC's applications packages have some type of tutorial or on-line help component which can be considered embedded training. As with most of the other Air Force organizations we visited, none of the SSC personnel we spoke to had heard the term "embedded training" used to describe software which provides training in the form of help or assistance.

Because the SSC acquires general purpose rather than specialized systems, its embedded training needs differ dramatically from those of ESD and ASD. As we noted in Chapter II, the embedded training in specialized computer systems is usually oriented toward teaching procedural skills to operators of signal processing systems and is normally oriented toward the practice of emergency or wartime skills. The embedded training capability in a signal processing system is used to prepare the operator to respond quickly and correctly in threat situations. For operators of standard systems, the need to act quickly and correctly is not critical. Instead, users of standard systems most often need to be trained to use a given software application.

The SSC's largest training problem is that its users often experience difficulty in learning to operate the systems it acquires. At least two interviewees noted that for whatever reason, planning for training tends to be left out during the system specification development process. It was reported that training was omitted to reduce cost. Also development managers usually worked with the initial assumption that their systems would be so user-friendly that training would not be necessary. Almost inevitably, when a new system arrived in the field, users did not know what to do with it or how to operate it. Other means of training then had to be provided. They ranged from adding or enhancing on-line helps and tutorials to providing traditional instruction. Most users had a preference for traditional stand-up instruction. This was probably due to the inability of most user manuals, help functions, or CBT to handle the many unique individual problems and questions that users have.

The SSC might benefit from research to develop intelligent, context-sensitive help or job aids which could ease users' needs for instructors. Currently most job aids, software tutorials, or helps are quite insensitive to context and to users' perspectives. For example, users expect the "help" function in an applications program to provide information on the specific portion or function of the program being used at the time. If help for the application is sandwiched between several layers of help menus, the user can be frustrated. As a result, traditional classroom training is preferred. Additional research might be performed on the application of intelligent computer-assisted instruction (ICAI) in large standard systems. Its use could allow the user to query the system to determine precisely what is needed in the way of help to perform a specific function.

The SSC's most immediate need appears to be a means for incorporating informed training planning into its systems acquisition and development process. This planning task is complicated by the fact that most of the SSC's systems are used by two or more major commands. The capabilities and resources available to its target user groups may vary considerably. As an example, the Training Planning Team (TPT) for the Core Automated Maintenance System (CAMS) consists of representatives from the MAJCOMs, ATC, and SSC. Although this group

makes far-reaching decisions regarding training for standard systems software, they must frequently do so without the benefit of knowledge of research on what kinds of training (especially embedded training) are best suited to specific application problems.

CAMS also provides an example of how the SSC could use help in Total Training System planning. For example, the SSC ATC liaison office is developing CBT training for CAMS using Merlin (a CBT authoring system) whereas the ATC Technical Training Center is developing other CBT training using the Saber authoring system. Personnel we interviewed at the SSC reported that there were at least five separate efforts to develop CBT for CAMS.

We also found that the SSC does not always include specific training requirements in the specifications for a system. The SSC had determined that a sophisticated simulation capability which verged on embedded training was necessary for training on the Cargo Movement System (CMOS). However, this requirement was not included in the system specification because of the perception that it would increase system costs. Instead, the specification included a requirement for "orientation" training on the system. As with the OTH-B program at ESD, better information about the costs of ET could have led to improved training decisions.

AFSPACECOM

AFSPACECOM has embedded training capabilities in almost all of its space tracking and early warning systems. The use of embedded training is a very important part of its aerospace operator training programs. In some instances, the system's embedded training component is the only means by which trainees can get hands-on practice with actual operational equipment.

Some AFSPACECOM officials are wary of using on-line systems for training. Currently, they are seeking to reduce or eliminate the use of embedded training from the AFSPACECOM training program; their current aim is to use full and part-task simulators.

One of the reasons for AFSPACECOM's reluctance to use embedding training in operational systems is an incident in which simulated signals were mistaken for real ones. As a result of this mishap, simulation capabilities were ordered removed from all space surveillance systems. Although not everyone at AFSPACECOM believes that embedding training in operational systems is necessarily a bad idea, there is a definite uneasiness about embedded training. Therefore, some individuals within AFSPACECOM would not be very receptive to embedded training research.

However, not all systems are prone to the problem of simulated signals being mistaken for real ones. For example, AFSPACECOM personnel who had worked with the IBM 4381 system at Falcon AFB said that there was virtually no chance of simulated signals "contaminating" the system. If the segregation of simulated data from real data can be achieved in this system, it could be achieved in others. The real problem may lie not with the embedded training, but with how some AFSPACECOM systems have been engineered and how they are used for training. These specific AFSPACECOM problems need research.

A secondary source of reluctance to use embedded training by AFSPACECOM reflects problems with scheduling training time on the operational equipment. System equipment is often in high demand, not only for operational use but also for maintenance, for software development, and for testing. On-the-job training has a relatively low priority. Frequently, trainees must deal with real-world interruptions during training exercises. Some managers within AFSPACECOM take the positions that off-line simulators would make more training time available and that such training time could be concentrated on specific requirements.

Although some AFSPACECOM managers seem opposed to continued use of embedded training, it appears that the Space Systems Division (SSD) has taken some initiative in the area of developing standards for the various types of simulation ET. One AFSPACECOM interviewee mentioned that SSD/CWOL has issued a draft document which addresses the issue of simulation standards. However, we were not able to determine exactly what standardization issues were addressed by the document (i.e., whether it specified a system configuration, or programming techniques, or minimum simulation capabilities, or some combination of these).

We believe that AFSPACECOM has a definite need for embedded training. Alternative means of providing hands-on training are not yet widely available. Moreover, AFSPACECOM has an ongoing need for Mission Readiness Training (MRT) for qualified crewmembers. The systems operators need some means of practicing and improving their job skills.

In approaching AFSPACECOM regarding embedded training research, it would be best to view their problem in the context of operational readiness. The Laboratory should talk to AFSPACECOM about their need for an effective and inexpensive means of providing operator readiness training, for which improved embedded training might be one of the possible solutions.

"Researchable" Embedded Training Issues

Some of the user problems regarding embedded training potentially could be solved through research. Other problems require non-research solutions. Perhaps the most serious, all-pervasive problem associated with embedded training stems from lack of widespread user awareness of the medium. Consequently, potential users have little interest in embedded training as a solution to their training problems. As we have pointed out, even those organizations who are currently using embedded training often do not call it by that name. Understandably, there is little or no dialogue among major commands and organizations to share information about embedded training because no one thinks of it as a fully capable training medium. Embedded training is perceived as an equipment-specific capability rather than a separate phenomenon which can fit into a total training solution.

The lack of awareness of embedded training as an acceptable part of a total training solution might reflect the lack of a single point of focus for embedded training in the Air Force. Unlike the Army and Navy, the Air Force has no official directive which requires program managers to consider embedded training during the acquisition process. Moreover, the Air Force has no central coordinating agency to take the lead in its embedded training efforts. The other Services have recognized organizations with responsibility for information and guidance regarding embedded training. The Army has the Program Manager for Training Devices (PM-TRADE) and the Army Research Institute (ARI). The Navy has the Naval Training Systems Center (NTSC).

The consequences of this lack of awareness by potential Air Force user agencies about embedded training are:

1. A failure to capitalize on the proven efficiency and overall quality of embedded training. Organizations must constantly re-learn lessons and make the same mistakes over again because they are not aware of what they can learn from others with similar experiences. Or, they simply fail to do things that would have been possible if they had known how to plan properly for the use of embedded training.

2. A hampered ability to improve embedded training by research efforts. It will be difficult to get support for an embedded training research program because users may not immediately realize how it can benefit them. In other words, it will be difficult to make embedded training better until you get the users' attention and the users decide that they need an improved training capability.

Until more Air Force user organizations develop a broader understanding of embedded training, persuading them to support embedded training research will be very difficult. However, there are some specific areas where research may be of value to the customers we visited. These areas are outlined and discussed below:

1. Embedded Training System Architecture

2. Assessment of Cost and Training Effectiveness of Embedded Training

3. Optimal Features of an Embedded Training System

4. Role of Embedded Training in a Total Training System

5. Development of Specifications for Embedded Training

Embedded Training System Architecture

Embedded training systems often fail to be implemented because of real or perceived technical obstacles. When embedded training systems are implemented, they often fail to incorporate desirable training features. Poorly designed embedded training can fail to increase readiness skill while reducing operating system performance. Thus, embedded training designers and developers would benefit from guidelines which help make embedded training architecture more efficient and, perhaps, more standardized.

Embedded training designers and developers must adapt to a variety of host systems. Devising meaningful guidelines could be difficult. However, guidelines would provide two payoffs. First, users would know what kind of operational characteristics they can expect in the embedded training for a given class of system. Second, such guidelines would assure "safe" implementations of embedded training.

What kinds of guidelines would be useful? At the highest level, guidelines are needed which provide the designers and developers with a rule of thumb for assessing embedded training costs. These guidelines should take into account all or most of the risks associated with adding an embedded training capability to a system. They should also take into account the varying levels of sophistication possible in embedded training scenarios. More specific guidelines could help System Program Office personnel to understand the range of embedded training features available and the incremental cost and technical impact of incorporating these features on the system. For example, because signal processing systems usually have a built-in system test capability, adding a rudimentary form of embedded training (i.e., providing a few practice scenarios) is likely to be a cheap and technologically feasible alternative. However, making "smart" scenarios, adding a performance recording capability, or providing the users with a simulation authoring capability might increase costs significantly and might provide system designers and developers with difficult technological problems.

Assessment of Cost and Training Effectiveness of Embedded Training

The people we interviewed could not produce separate cost figures for the embedded training component of their systems. Most guessed that the addition or inclusion of the embedded training capability had a relatively minor impact on the overall cost of system acquisition or development; however, they could provide neither specific figures nor a percentage estimate. The inability of program management personnel to assess the actual costs of embedded training was usually due to the fact that the embedded training component of the system utilized the system's built-in test capability (e.g., PAVE PAWS, BMEWS and AWACS). Because embedded training costs are usually "included" in a system's basic test capability, costing embedded training separately could not be done by those program offices. If the Laboratory were to become involved in assessing the cost impact of embedded training, accurate cost figures could probably be obtained from programs like the F-16 OBEWS which were specifically designed as embedded training systems. All the costs of such a project would be directly related to the embedded training.

Assessments of embedded training effectiveness were similarly informal. Those training effectiveness assessments which we found consisted merely of gathering comments from system users in the field and assessing subjectively whether operator performance had improved. (It might be noted that everyone we talked to reported that the embedded training capability of the system helped improve crew performance.) We do not doubt that embedded training has had a positive effect on crew performance. However, up to now the extent to which operational proficiency is improved by embedded training has not been measured systematically.

Most of the user organizations that were actually using embedded training in the field were not particularly disturbed about the lack of cost and training effectiveness data. They already had their systems in place and had no need to re-justify them. However, the lack of effectiveness data *is* a problem for organizations like ASD, which are assessing whether or not they should add embedded training to existing or future systems. It is not as difficult a decision for AFSPACECOM to make regarding the inclusion of embedded training in a new system, as their systems have traditionally come with the capability built-in. ASD does not have this luxury. ASD must decide whether to add embedded training, and they need the kind of information necessary to make this decision.

Optimal Features for Embedded Training

It is not yet clear what functions or features an optimal embedded training system ought to have. Several attempts have been made to specify what features "good" embedded training should have. Little research has related embedded training features to specific job skills or assessed the cost effectiveness of particular training features. The Army Research Institute has suggested the following features as representative of fully functional embedded training (Strasel, Dyer, Roth, Alderman, & Finley, 1988):

1. Generates target or threat data;

2. Feeds these data into and through the operational equipment to the system's operator(s) or maintainer(s) by means of their normal displays and indicators;

3. Presents the input data so as to realistically depict what would occur in an operational exercise of the system against a real threat;

4. Requires the operator(s) or maintainer(s) to perform their normal and proper tasks and duties in response to the simulated mission inputs;

5. Simultaneously and interactively assesses and records the performance of the operator(s) or maintainer(s) and reacts to that performance as the real threat would;

6. Provides an appropriate level of performance measurement and recording to allow both individual feedback after a session and semi-permanent records of performance; and

7. Usually allows for the presentation of computer-assisted or otherwise programmed instruction on related job-relevant tasks and sub-tasks in addition to those which are strictly operational mission performance tasks.

ARI's set of criteria provides a view of what an "ideal" embedded training system would look like. However, it does not address the trade-offs that would need to be made if a "fully functional" embedded training system were too expensive, technologically too difficult, or not needed to meet training requirements. For example, if synthetic threats have caused false alarms, to what extent can the threats be presented less realistically without diminishing the value of practicing with them? What aspects of an operator's performance need to be recorded? Is supplemental computer-assisted instruction on a separate system acceptable or must training be limited to the host system?

We have found that embedded training features vary widely from system to system. On-line feedback is seldom incorporated. The degree of inclusion of other features varies widely among systems. For example, systems vary in the degree to which they allow scenario authoring. Some have a rewind capability, but not a fast forward capability. Others have the opposite. Some have a scenario freeze capability; some do not. Moreover, not all embedded training features are used even if they are available in the system. For example, the PAVE PAWS embedded training system can record the specific switch actions made by a trainee during scenarios. However, this capability is seldom used by AFSPACECOM to evaluate crew performance or to provide immediate feedback to the trainee. In our opinion, the capabilities of many currently fielded embedded training systems only coincidentally meet the needs of the operational units. There is no hard evidence to suggest what features do and do not contribute to mission readiness or enhancement.

ASD has expressed an interest in research on the types of real-time feedback needed and the types of performance measurement needed for embedded training systems. Although other organizations such as ESD and AFSPACECOM have not expressed such interest, their use of embedded training could probably also benefit from research in these areas.

Role of Embedded Training in a Total Training System

The role of embedded training in the total training picture for a given system varies with the type of embedded training. With simulation ET, the embedded training is normally used for the practice or rehearsal of operational skills. Other training events, such as instruction or feedback, are usually provided by supervisors or workbooks on-site. With job aiding, the role of the embedded training is to provide assistance to the user whenever needed. With tutorial ET, the embedded training may encompass all events of instruction from reminding the user of related background information to presenting material to be learned for the first time and testing the operator-trainee's retention and transfer of the material.

To date, decisions about the role of embedded training in the Air Force total training system have been avoided because of a lack of good information about embedded training. In

organizations like ESD and SSC, the ultimate "decision" about the inclusion of embedded training in a system and the specific features of the embedded training has often passed by default to the designers or developers of the system. The users (e.g., AFSPACECOM) have, for the most part, simply made do with what they were given. Embedded training has seldom been a focus of attention during the acquisition process.

The current approach to embedded training development has worked more or less successfully for organizations like ESD and AFSPACECOM. Over a long period of time, the users have come to expect practice capabilities in their operational systems. However, the current approach is much less helpful to organizations like TAC, Strategic Air Command (SAC), and Military Airlift Command (MAC), which have little or no experience in using embedded training. The addition of an embedded training capability to a system must result from a deliberate effort by these organizations to address their operational training requirements. We believe that it would be helpful to the MAJCOMs and ASD to have better information for determining the best applications for embedded training within total training systems.

Development of Specifications for Embedded Training

We have found that specifications for major systems such as PAVE PAWS, BMEWS, or AWACS tend not to address the issue of embedded training because the program office personnel are engineers who have little or no experience in addressing training issues. The fact that these systems include an embedded training capability at all is due to the program office's clear understanding of the requirements from the user command that operator personnel must be able to practice those skills which are needed in emergency or wartime situations. More recent specifications (i.e., those for the ATF in particular) have addressed the potential need for embedded training. However, the requirements which could be met with embedded training are not well defined in these specifications. Usually, the specification directs the contractor to investigate the possible use of embedded training. From the point of view of cost effectiveness and training effectiveness, this practice appears to be very risky. Usually, the more details that can be included in a specification, the more accurately costs can be estimated and the closer training results will conform to Air Force expectations.

We think one reason for the lack of detail about embedded training in specifications may be that acquisition agencies are afraid of driving up system costs with "nonessential" components. Acquisition agencies currently have no way of accurately specifying the parameters of an embedded training component of a system. They also have no way of ensuring that contractors or developers use a logical and systematic method for determining which training requirements should be addressed by embedded training and which should *not*. As a result, they include embedded training in specifications only to the extent that they feel it will *not* impact system costs.

The development of guidelines for embedded training specifications must follow from a determination of some acceptable way(s) for embedded training to fit into the total training picture. This should include the development of guidelines for determining: (a) what kind of requirements embedded training could potentially address; (b) ways of determining the cost impact of selecting embedded training as a medium; and (c) ways of selecting the various features of an embedded training system. All of these research issues need to be addressed prior to the development of guidelines for embedded training specifications.

IV. POTENTIAL ROLES FOR AFHRL

The Embedded Training R&D Market

The previous chapter focused on the problems of potential customers and tried to identify problems that could be "solved" with R&D. This chapter will focus on AFHRL's relevant strengths vis-a-vis those of other R&D organizations.

Private Sector Capabilities for Embedded Training R&D

For the purpose of describing private sector capabilities, it is probably more accurate for us to think in terms of markets from which ET-related R&D might emerge, rather than to view embedded training R&D as an established market. We were able to identify four such markets:

1. Electronic Systems Development
2. Operations Training Hardware
3. Training Systems and Services
4. Software for General Purpose Computers

In the following sections, we will describe some representative companies from each of these markets which have either developed embedded training systems or performed ET-related R&D. We will also assess generally how companies from these markets could contribute to an embedded training R&D effort.

Electronic Systems Development Market

Private sector organizations in the Electronic Systems Development market include companies such as Raytheon's Electromagnetic Systems and Missile Systems Divisions, Litton Industries' C^3 Systems Group, General Electric's RCA Electronic Systems Division and Grumman. Raytheon's involvement includes the development of the PAVE PAWS and BMEWS early warning systems, and the Patriot missile system. Litton developed Modular Control Equipment (MCE) in a joint project for the Marine Corps and the Air Force. RCA developed the AEGIS shipboard missile weapon control system. Grumman's division in Melbourne, Florida, is currently working on the advanced radar systems on the Joint Surveillance Target Attack Radar System (JSTARS).

The private sector companies in the Electronic Systems Development market compete with each other on the basis of the overall functionality of their systems. Although their systems can usually be modified to include embedded training, they generally do not perceive themselves to be primarily developers of training or of training systems. From the perspective of embedded training R&D, much of their strength lies in the area of system design, system development, and the production of large electronic systems.

AFHRL does not compete in the Electronic Systems Development market. However, it may be able to draw upon the expertise of one or more of these companies in undertaking R&D problems related to the design and engineering of embedded training within large electronic systems.

Operations Training Hardware Market

The Operations Training Hardware market is composed of companies which produce equipment that can be used for operations training or mission rehearsal training. This market also contains smaller sub-groups of companies which produce particular types of operations training equipment. For example, both Loral Electro-Optical Systems and Saab Training Systems produce laser transmitters which can be strapped onto weapon systems to simulate the effects of live ammunition. Raytheon's Submarine Signal Division, United Technologies' Norden Systems, and United Industrial Corporation's AAI all produce devices which can be used to inject signals into shipboard radar and sonar systems for training purposes. AAI has applied this technology to EW training aboard aircraft via its F-16 OBEWS project.

Unlike the companies in the Electronic Systems Development market, companies in the Operations Training Hardware market openly compete for training business. Their competitive edge in this market results primarily from their capabilities to produce training hardware. These companies have training specialists on their staffs, and they are familiar with the types of documentation associated with the Instructional Systems Development (ISD) approach to training. Decisions about the appropriate instructional application of their equipment are often left to the users.

Although it can be said that the companies in this group are producers of embedded training, they have not made a point of marketing themselves as such. Instead, they perceive themselves to be competing in more limited markets to produce "on-board trainers," "radar stimulators," or "laser transmitters." Conceivably, they could market themselves as embedded training experts, but they gain little competitive advantage at present by using the term. Their customers know what kind of services and products they provide.

AFHRL could probably look to the companies in this market sector for technical R&D solutions to training problems. F-16 OBEWS, for example, is a solution to the problem of providing EW training when ranges are not available. Companies in this market could be valuable teammates in any AFHRL endeavor to develop an embedded training testbed which involves the development of hardware.

Training Systems and Services

Companies in the Training Systems and Services market have tended to concentrate on the study and support of embedded training rather than on the development of full-scale systems which include an embedded training component. This group is primarily composed of relatively small players, but some larger firms have also gotten involved.

Some of the smaller companies in this market include Applied Sciences Associates (a subsidiary of Analysis and Technology), Hi-Tech Systems, Vector Research, Eagle Technology (a subsidiary of Logicon), and Dynamics Research Corporation. Applied Sciences Associates (ASA) produced the ARI-sponsored tri-Service review of embedded training components (Warm, Roth, Sullivan, & Bogner 1987). ASA and Hi-Tech Systems collaborated on a project to assess lessons learned from the application of embedded training design guidelines to an emerging system, the All Source Analysis System/Enemy Situation Correlation Element, or ASAS/ENSCE (Evans, Adams, Simkins, Aldrich, Dyer, & Narva, 1988). However, ASA is better known for developing the 10-volume set of guidelines for implementing embedded training (Finley et al., 1988). Hi-Tech Systems and Vector Research were also contributors to this effort.

Eagle Technology's efforts have included assessments of embedded training technology and recommendations for embedded training R&D for both the Navy and the Air Force (Malehorn, 1985a, 1985b, 1986). E-Tech has also developed the SPA-25G Embedded Training System (SETS) for the Navy's SPA-25G radar (Jorgensen, 1986, 1987; Jorgensen, Hoskin, & Manglass, 1988; Jorgensen & Muse, 1986). Unlike the systems described in the previous section on Operations Training Hardware, this project was undertaken as a training development effort from the onset. Although software engineering skills were needed to integrate the system and develop its software, no hardware development was involved. The training developed for the system was designed within the ISD process. Finally, E-Tech has evaluated in-place embedded training systems to develop guidelines for new systems, specifically the AN/BSY-2 Combat Control System for SSN-21 submarines (Hoskin, Jorgensen, & Manglass, 1988).

Dynamics Research Corporation (DRC) produced a 4-volume set of reports evaluating the potential for embedded training aboard tactical aircraft for ASD/XR (O'Brien & Hess, 1988). Based on their recommendations, a follow-up study was later conducted by the Fort Worth Division of General Dynamics, in which these concepts were tested out in a simulator (Davis et al., 1986; McNeley et al., 1988).

To our knowledge, with the exception of General Dynamics, all of the above-mentioned companies performed their embedded training work while still small businesses. All market their services in the training systems and services arena, which is where they won their embedded training contracts; and all utilize personnel with training expertise.

AFHRL could probably look to the various companies in this market sector for general training expertise, particularly in areas such as training needs analysis. Given their experience with training, these companies would probably view embedded training in the context of the total training picture.

Although these companies can also provide instructional design and development services (as evidenced by E-Tech's work with SETS), their role in the actual development of major systems with embedded training components is probably limited. Because these companies do not usually develop hardware (i.e., operational equipment), it will be difficult for them to get involved on the "ground floor" of embedded training for major systems development except as a team member or subcontractor with one of the major defense system development firms. This is not an unlikely scenario for these companies. However, due to the fact that embedded training tends to be perceived as a practice medium currently, rather than as an instructional medium, there may not be a widespread demand for instructional development expertise.

Software for General Purpose Computers Market

For the most part, the literature on embedded training systems in the military does not recognize training that occurs on general purpose computer systems to be embedded training. This type of training is usually considered to fall under the rubric of computer-based training or on-line help. However, if this type of training were included in the definition of embedded training, there are a number of companies which could potentially become involved.

There are three avenues by which companies could participate in embedded training development in this market. The first is by developing computer-based training or job aiding to accompany software applications. The second is by providing some form of programming or authoring capability so that users themselves can develop training if they wish. Both of these approaches are fairly conventional and well explored. The third is by concentrating on developing innovative solutions or approaches to training on these systems. Generally, this involves the use of Artificial Intelligence (AI) programming techniques.

Major Government contractors which develop training or provide job aiding for the applications they produce include UNISYS, Zenith, Computer Sciences Corporation, and IBM among others. There are also a number of companies which primarily market their CBT development services; these companies could be contracted to develop training for an existing application. These companies include Flight Safety International, CAE-Link's Allen Corporation and McDonnell Douglas Computer Based Training Systems. Several of the companies in the Training Systems and Services market are also able to provide CBT.

Companies which provide programming or authoring capabilities with their systems include UNISYS, Honeywell, Wang, and IBM. Generally, these capabilities are included with larger, mainframe systems; and generally, they allow users to produce either CBT lessons or help screens. However, the programming or authoring capabilities are usually much more limited than what could be found in a full-blown programming language or CBT authoring package.

Some organizations with experience in providing specialized software include Lockheed's AI Center; Bolt, Beranek, and Newman Laboratories, Inc. (BBN); the University of Central Florida's Institute for Simulation and Training; and Southwest Research Institute. All of the above-listed companies have explicitly indicated an interest in embedded training R&D. BBN has already produced an embedded training technology survey for ARI (Massey, Harris, Downes-Martin, & Kurland, 1986). BBN has also been involved with intelligent tutoring systems development since the mid-1970s (Collins, Warnock, & Passafiume, 1975).

AFHRL could look to any of the companies in this market sector for both software engineering and training development skills. However, the companies which market innovation, rather than systems or training packages, are the most likely partners for embedded training R&D in support of the SSC's needs.

Multi-Market Competitors

There are some companies which are so large and/or multi-faceted that they could compete in several of the above markets *or*, conceivably, consolidate some of their resources so that they can compete in the embedded training market in a more comprehensive way. Companies like Boeing, Lockheed, IBM and McDonnell Douglas, for example, have divisions for training, electronics, and aircraft. Although these divisions are often managed independently, these companies could in theory marshall their resources to present a total systems approach to the development of embedded training.

Many such companies are interested in becoming more involved in embedded training research and development. Boeing Military Airplane's Simulation and Training Group, for example, recently completed an Independent Research and Development (IR&D) project which proposed an embedded training capability on current and future weapon systems (Leishman, 1989). Both McDonnell Douglas and Ball Systems are currently involved in the development and testing of the F-15 On-Board Simulator (F-15 OBS) for the Flight Dynamics Laboratory (WRDC/FIGX). Logicon was involved in the development of an embedded training component for the CINC-PACAF Integrated Decision Support System (CIDSS). Of course, the two ATF teams (General Dynamics/Lockheed/Boeing and Northrop/McDonnell Douglas) are also capable of marshalling the necessary capabilities to provide comprehensive embedded training R&D for that aircraft.

At present, these companies' potential for embedded training involvement remains just that--potential. Most appear to be waiting for the Air Force to sanction the use of embedded training. At the recent Interservice/Industry Training Systems Conference, McDonnell Douglas and Ball Systems company representatives indicated that although they were interested in embedded training development, they could not do much until the Air Force begins to request

it. If and when the Air Force begins to encourage the use of embedded training, such companies certainly have the capabilities in-house to bring to bear on a variety of aspects of embedded training R&D.

Depending on one's viewpoint, embedded training can be considered either an old or a new technology. Companies which develop electronic systems have been developing a form of embedded training for years. But embedded training itself has only just begun to catch the attention of training specialists. It is not inconceivable that in some larger companies, one division could be trying to break into the embedded training market, while another has been developing it for years.

As for active, conscious involvement in embedded training R&D, no one company seems to be the market leader. Most private sector companies have worked on a single project or perhaps a few related projects. Only a few small companies, such as Applied Sciences Associates and Eagle Technology, have made a concerted effort to develop and promote their "embedded training" expertise.

The DoD Embedded Training R&D Agenda

AFHRL is not the only Government organization looking at embedded training. The Joint Technical Coordinating Group for Training Systems and Devices (JTCG-TSD) has established a tri-Service working group to coordinate and oversee embedded training within the Services. JTCG-TSD has proposed an embedded training Study Plan (1989) which is oriented around five major embedded training R&D tasks. JTCG-TSD's first task is to "evaluate effectiveness of in-place embedded training systems (air/surface/submarine) including maintenance trainers." Tri-Service research efforts in support of this task include a joint ARI/PM TRADE effort, *Tri-Service Review of Existing System Embedded Training Components* (Warm et al., 1987) and an NTSC effort to evaluate embedded training for sub-sea systems with a view toward application to AN/BSY-2 training system design (Hoskin et al., 1988). The reports from these two projects do an excellent job of describing and evaluating the systems they cover. However, their work is of limited relevance to Air Force systems. The ARI/PM TRADE study covers three Air Force systems: WWMCSS, F-15 OBS, and AWACS. The NTSC AN/BSY-2 study focuses on undersea systems. Also, the JTCG-TSD effort has tended to look to the Air Force for embedded training R&D which is specifically related to airborne systems (more particularly pilot training) when, in fact, the Air Force has been regularly employing embedded training in its large ground-based sensor systems since the 1950s. An AFHRL effort to evaluate existing Air Force embedded training systems could enhance the tri-Service effort by contributing useful data about these systems (particularly ground-based systems), and by providing more system-specific data for the systems being evaluated. Air Force ground-based radar systems are in many ways quite similar to Navy and Army radar systems. Cross-over lessons about embedded training could be learned by each Service from studies of these systems.

The expressed purpose of the JTCG-TSD's second task is to investigate selected tri-Service classes or sub-classes of materiel items to determine problems, constraints and impediments to embedded training implementation, and to analyze the resulting data to define potential research programs or administrative action that might develop solutions to these problems. Tri-Service efforts which support this task include two Air Force projects, and several other Army and Navy projects. The Air Force projects are the completed ASD/XR project *Embedded Training Concepts for Tactical Aircraft* (O'Brien & Hess, 1988), and a WRDC/FIGX project currently in progress involving the Air Combat Engagement System. The Army projects were the ARI 10-volume study, *Guidelines for Implementing Embedded Training Systems* (Finley et al., 1988), and a PM-TRADE effort to derive embedded training system concepts and strategies for the Armored Family of Vehicles. The Navy projects consist of an NTSC concept demonstration effort to develop embedded training for the SPA-25G radar repeater; another

NTSC effort to identify training technologies which can be incorporated in embedded training systems; and an effort to develop the Battle Force Research Simulator (BFRS), a testbed for shipboard embedded training systems and concepts.

The JTCG-TSD's third research task is to develop a centralized embedded training database. According to the Study Plan, the performing agency and funding source for this task have yet to be identified. The task would involve more than simply collecting information from the Services; it would also require defining who the users would be and their information needs, selecting appropriate hardware and software, and finding a host organization to house the database and staff the facility.

JTCG-TSD's fourth task is to conduct a case study of potential embedded training applications for Unmanned Aerial Vehicles (UAVs). The performing agency and funding source for this task have not yet been identified, and the task itself appears to be in the definition stage at the moment. It would appear that the task is oriented solely toward the Army.

Finally, JTCG-TSD's fifth task is to "develop guidelines and exemplar products for incorporating embedded training requirements in System Requests For Proposal (RFPs) and for evaluating proposals under the Proposal Evaluation Plan (PEP)." Two ARI projects support this task. One is a completed ARI effort to develop embedded training guidelines for the Armored Family of Vehicles; the other is an ongoing ARI effort to take these Armored Family of Vehicles guidelines through the Proof-of-Principle phase to the development of Concept Formulation Packages for initial prime-item Heavy Forces Modernization Program implementation.

The Joint-Services agenda is oriented primarily toward the Army and the Navy. It does not address adequately the needs of the Air Force customers we identified in Chapter III.

AFHRL's Special Strengths Vis-a-Vis Embedded Training R&D

No one has taken the lead in conducting embedded training R&D for the Air Force. AFHRL's strengths would better suit it for some embedded training research roles than for others. AFHRL's organizational strengths with regard to embedded training R&D are, first, its natural competitive advantages as an Air Force R&D organization; and second, the resources and talent it already has on board which can be brought to bear on embedded training R&D. We believe some of AFHRL's relevant advantages to be as follows:

1. Existing Contacts with Potential Embedded Training R&D Customers

2. Job Analysis Expertise

3. Specific Training Expertise

4. System Design Expertise

Existing Contacts with Potential Embedded Training R&D Customers

As previously mentioned, AFHRL already has established close working relationships with several potential customers via its ongoing programs. Few other organizations can match AFHRL's extensive Air Force customer base. Several AFHRL customers have a high degree of potential for supporting embedded training research (e.g., AFSPACECOM, ASD, ESD, Pacific Air Forces (PACAF), and the major Continental U.S. (CONUS) flying commands). These

existing contacts give AFHRL an edge over other R&D organizations in terms of established relationships with potential customers.

AFSPACECOM is an important potential customer because the command uses embedded training in its large-scale radar systems. The Logistics and Human Factors Division (AFHRL/LR) has had a close working relationship on several projects with AFSPACECOM. In addition, AFSPACECOM has formally requested AFHRL's assistance fo C^2 training research. The Ground Operations Branch (AFHRL/LRG) is currently engaged in several projects related to C^2 Team Training, including development of a C^2 part-task trainer for AFSPACECOM. AFHRL/LRG also participates with ESD in the Strategic Defense Initiative (SDI) and Battle Management/Command, Control, and Communications (BM/C^3) programs. AFSPACECOM and ESD could identify issues on which AFHRL/LR could perform embedded training research.

Both the Manpower and Personnel Division (AFHRL/MO) and the Operations Training Division (AFHRL/OT) have previously established contacts at ASD, TAC, SAC, and MAC. AFHRL/MO's support for these customers includes job/task analysis. AFHRL/OT's support of its customers consists primarily of conducting aircrew training research; disseminating its accumulated findings and expertise to users; and, development of new technologies for aircrew training. The involvement of these two divisions provides AFHRL with a comprehensive view of aircrew training and a full spectrum of training contacts at ASD and the flying MAJCOMs.

Most of the Training Systems Division's (AFHRL/ID) current contacts do not appear to be potential embedded training research customers. The Air Training Command, an important AFHRL/ID customer, does not appear to be a potential embedded training R&D customer. ATC deals primarily with training initial skills, which tend to utilize dedicated training equipment or simulators rather than actual equipment; embedded training, by definition, requires the use of actual operational equipment.

Job Analysis Expertise

AFHRL also has an edge over potential private sector competitors insofar as its previous work with such a wide range of Air Force customers has given AFHRL insight into the training needs of particular job categories. Some of these job categories, such as Command and Control (C^2) systems operations and aircrew positions, have a high potential for the use of embedded training, because of their requirement for signal processing skills. Several AFHRL divisions have worked extensively with one or more of these job categories, and are therefore quite familiar with the training requirements for these positions.

Knowledge of the skills required for specific occupational specialties provides AFHRL an advantage in working on embedded training problems. Because one of the primary problems in training in general, including embedded training, is related to the selection of the proper media, AFHRL's ability to identify these requirements for numerous Air Force specialties (AFSs) and match an appropriate medium with them to achieve training effectiveness and cost effectiveness will give it a distinct advantage over the competition.

For the purposes of embedded training R&D, AFHRL's familiarity with aircrew training (via AFHRL/OT) and Command and Control team training (via AFHRL/LR) is quite relevant. AFHRL/LR has an excellent understanding of C^2 job skills as a result of its research with the C^2 Team Training project. This research has enabled AFHRL/LR to build up expertise in task analysis, performance assessment, and trainer development for C^2 skills. All of these skills would be potentially transferable to C^2 embedded training research.

Both AFHRL/MO and AFHRL/ID have had extensive exposure to training requirements for maintenance specialties. AFHRL/MO has tended to focus on the analysis of maintenance job

skills, whereas AFHRL/ID's R&D efforts have centered on the development of systems and tools to support training development, such as the Training Decisions System (TDS), Job Performance Measurement and Training Assessment procedures, and development of advanced instructional technologies such as Intelligent Tutoring Systems.

Training Expertise

MO has accumulated a database containing Manpower, Personnel, and Training requirements data for existing Air Force weapon systems while in the process of developing tools for forecasting life-cycle costs (LCC) of new technologies. As information about the cost and use of embedded training becomes available, it could be incorporated into this database. AFHRL/MO may be able to develop a similar model to estimate what impact adding embedded training has on the overall training and LCC for a given system. This new model would enhance the existing AFHRL/MO LCC models.

AFHRL/ID has several programs which could potentially be extended to embrace embedded training R&D. These include the Job Performance Measurement (JPM) R&D program, the Training Decisions System (TDS), and AFHRL/ID's work on Intelligent Tutoring Systems (ITS) development. The JPM project, which is designed to develop procedures for selecting, developing, administering, and interpreting measures of training effectiveness, could conceivably be augmented to include embedded training. The TDS, which helps users evaluate the costs and benefits of various training alternatives, could easily be expanded to include embedded training as another training alternative to be considered in the Air Force concept of total training. AFHRL/ID's work in ITS could be the basis for a project oriented toward applying AI techniques to embedded training, such as the development of intelligent, context-sensitive job aids to accompany applications software packages.

AFHRL/LR's programs on C^2 training could very well be augmented to include an investigation of embedded training. At present, the Ground Operations Branch (AFHRL/LRG) is involved with several projects for AFSPACECOM, PACAF, and several other users. Most of these projects are small and oriented toward development of a single training system. The projects include a part-task trainer for AFSPACECOM, a prototype training system for PACAF, another prototype training system for Modular Control Equipment (MCE) teams for ESD, and a prototype training system for Logistics C^2. All of these projects represent prototypical, dedicated training systems and do *not* include embedded training.

Finally, AFHRL/OT's efforts to produce design guidelines and specifications for aircrew training systems could be augmented to include the development of guidelines and model specifications for embedded training. At present, AFHRL/OT's efforts have centered on gathering data related to the improvement of aircrew training.

Systems Design Expertise

AFHRL/LR's work on Computer-Aided Design/Computer-Aided Engineering (CAD/CAE) involves the development of tools that enable engineers to consider the reliability, availability, and maintainability trade-offs they would be making in adopting particular designs. With the right kind of data about embedded training system architecture, the same kinds of tools might be extended to assess the impact of adding an embedded training component to a system.

Where AFHRL Could Make Important and Unique Contributions

If AFHRL becomes involved in embedded training R&D, it would have a competitive edge in addressing the following R&D issues. These are areas in which AFHRL has unique strengths:

1. Job Performance Measurement. AFHRL could apply its accumulated knowledge of job performance measurement to the task of identifying what performance measures are needed for embedded training.

2. Manpower, Personnel and Training (MPT) Integration. MPT integration technologies could be modified to reflect the impact of the use of embedded training on the life-cycle costs of a system.

3. Concurrent Engineering. AFHRL could build on its experience with the development of Reliability, Availability, and Maintainability in Computer-Aided Design (RAMCAD) and ergonomics (CREW CHIEF) to develop similar tools for embedded training design considerations and trade-offs.

4. Investigation of the Feasibility of Embedded Training for Specific Job Categories. AFHRL is particularly well equipped to explore implementations of embedded training in the areas of Command and Control, aircrew operations, and maintenance.

5. Applications of Artificial Intelligence (AI) to Training. AFHRL has had extensive experience in cooperative efforts to apply AI to training. This experience could well be applied to the development of solutions to the problem of training the users of applications software.

AFHRL should undertake R&D in the following areas only with the assistance of experienced private sector firms or other DoD agencies which have particular strengths upon which AFHRL could capitalize. These are areas for which either (a) AFHRL has some experience, but not necessarily unique strengths; or (b) AFHRL can profitably team with others because of the advantage it would bring:

1. Embedded Training Design Issues. These are issues which pertain to determining the form and features of embedded training, but which stop short of actually producing hardware/software. These issues may include R&D on safe implementations of embedded training for aircraft; determination of whether or not standardization of embedded training features is possible and/or desirable; and assessment of the incremental economic/instructional benefits of adding particular features to embedded training systems.

2. Definition of the Role of Embedded Training in a Total Training System. Although AFHRL does have strengths in terms of its ability to research Total Training Systems, other Air Force organizations, such as ASD and ATC, are also heavily involved in this area. Moreover, the other Services have embedded training researchers who have been working with this issue for some time. It would be advisable for AFHRL to pursue a joint approach to this problem.

3. Development of Model Specifications for Embedded Training. Again, although AFHRL has considerable experience in the development of model specifications, it could benefit from cooperative efforts with other Air Force organizations and the other Services in this area.

AFHRL should avoid undertaking R&D in the following area because of a lack of expertise and the high risk associated with such R&D:

1. Hardware or Software Development. AFHRL is not well equipped to take on the development of embedded training hardware or software. Whenever possible, it should try to perform research on systems being developed or acquired by its customers. For example, WRDC/FIGX and ASD/ENE previously requested AFHRL to conduct embedded training R&D with the Air Combat Engagement System (ACES).

V. RECOMMENDED IMPLEMENTATION STRATEGIES

Potential Technology Development Areas

Chapters II and III discussed trends in the use of embedded training and potential users' needs. Chapter IV looked at potential strengths that AFHRL could bring to embedded training R&D. This chapter identifies a set of R&D issues which are derived from significant user needs, and which AFHRL is well suited to address. These issues could form a potential embedded training R&D agenda for AFHRL. We suggest neither that this agenda is complete nor that all the issues have to be addressed by AFHRL. For some of the issues on the agenda, the risk may be too great or the payoff too small. However, we feel that any embedded training research implementation strategy would address some of these issues.

In each of the following sections we will outline an R&D issue which AFHRL could investigate. Each R&D issue is discussed in terms of the technology development area, the potential customers, the relevant AFHRL strengths, and the risks involved.

The Safety of Embedded Training Systems

Technology Development Area: On the basis of their existing working relationship with AFSPACECOM and the high concentration of embedded training systems at AFSPACECOM, AFHRL/LR could take the lead in a study for AFSPACECOM. This effort might possibly be combined with some other new or ongoing AFHRL effort with AFSPACECOM, such as a project to assess alternatives for maintaining operational readiness. Such a study would describe in detail how the embedded training for a given system interfaces with the system hardware and software, how simulated signals enter the system, what types of operator switch actions are allowable, and the "smartness" of simulated targets. It could also assess the long-term effects of embedded training on the host system; the effect of and potential for adding features to the embedded training component; and user embedded training requirements.

ASD also has concerns about the safety of embedded training. AFHRL/OT could work with ASD to assess safety features required for airborne embedded training. A pilot test project using AFHRL/OT's simulators could be the first step in assessing the safety factors required for embedded training. Some of the key issues to concentrate on are those listed by ASD/ENE (see Chapter III). Such a project would also contribute to the JTCG-TSD embedded training agenda.

Potential Customer: Both ASD and AFSPACECOM have expressed concerns about the impact of embedded training on the safety, security, and performance of their systems. Some managers are consequently reluctant to use embedded training. ASD is expressing the concerns of the flying community, some of whom feel that any aircraft component which does not directly contribute to the operational mission is an added weight or burden to the aircraft and a potential safety hazard. This is an important problem because concerns about the safe

implementation of embedded training are currently inhibiting AFSPACECOM and ASD in their use of embedded training.

Relevant AFHRL Strengths: AFHRL/LRL's efforts to incorporate maintenance and logistics considerations into the hardware design process on such projects as the Ground-Launched Cruise Missile, the F-15E, and the Integrated Electronic Warfare System have enabled it to develop a certain degree of in-house software engineering expertise which could be used in projects of this type. To the extent that simulation equipment mirrors operational equipment design, AFHRL's Technology Development Branch (AFHRL/OTE) also has the appropriate engineering experience to initiate an embedded training research project involving safe embedded training for aircraft. AFHRL/OTE's perspective on aircraft training simulators should also be useful in recognizing and addressing the training issues involved in such research.

Risks: Although it has some engineering experience, AFHRL lacks the in-depth technical expertise in software engineering to conduct R&D involving the safe implementation of embedded training without some outside assistance. A contractor with sufficient software engineering expertise would reduce the technical risks of this project.

Intelligent Tutors for Standard Systems

Technology Development Area: Applications software is in use today in standard computer systems throughout the Air Force. There is a continuing need to identify specific user problems with the applications package and to train the users. Our site visits indicated that no amount of user friendliness in an applications package can match having an expert user nearby for assistance. Providing some type of intelligent job aids for applications software may be a potential solution.

The Laboratory could take the lead in supporting the SSC by developing job aiding software which could operate on the new Desktop III computers. This software might consist of some sort of expert shell which would allow applications software developers to create job aids for their users, and users to query the system to solve problems with the software.

The same kinds of AI applications which are developed to make the development of embedded training easier could also be used to create an embedded monitoring system for software applications. Such a monitoring system could check the user's ability to use all of the software features; it could monitor the user's need for specific help during an application, diagnose the specific problem, and prescribe training or remediation; and, it could provide "coaching" to the user.

Potential User Needs: The potential payoffs could be elimination of the cost of classroom training for software users, improved fixes to remedy difficult user interfaces, and time savings for innumerable users. Both the SSC and user commands should realize the benefit of research to eliminate or reduce the amount of user training required for applications software. The SSC program managers also need assistance in identifying those software programs which could benefit from an embedded training capability. Their ability to specify exactly what form the required embedded training should take is minimal without a methodology or decision aid for embedded training.

A user like the Accounting and Finance Center, which uses numerous software programs for financial applications on standard computer systems, would benefit from embedded training for these applications. The Accounting and Finance Center, as well as the entire Air Force Comptroller community, spends significant amounts of time training on-the-job for financial software applications. Ways of reducing these hours and/or increasing performance capabilities would be viewed as beneficial to the Air Force.

Relevant AFHRL Strengths: AFHRL's Intelligent Systems Branch (AFHRL/IDI) is at the forefront of Air Force research in the application of AI to training. The branch is currently involved in over 20 Intelligent Tutoring System (ITS) projects, and they maintain contacts with many of the leading researchers in the field. Among the ITS projects, the work on intelligent "microworlds" and rapid instructional development tools for ITSs (such as the Intelligent Computer-Assisted Training Testbeds) are particularly pertinent to the SSC and the Accounting and Finance Center.

Risks: The initial research required to develop solutions in this area will almost certainly be costly because of the rapidly developing state of the art in AI applications. Even if sufficiently intelligent job aids can be developed, developing them for individual software packages may add too much to the cost of the software. Alternative approaches to this problem may focus on the issue of developing a "generic" AI shell which can be applied across software applications, or developing a methodology for applying AI techniques to individual applications programs.

Linking Embedded Performance Measurement with Embedded Training

Technology Development Area: The Air Force has no way of determining the effectiveness of embedded training in general, or of specific embedded training features in relation to certain jobs. AFHRL/OT could concentrate on developing performance measures for one or two critical job positions (e.g., pilot, co-pilot, navigator, electronic warfare officer). A task analysis of the selected position(s) (describing both job tasks and required skill levels) would need to be made available, either from existing documentation or by conducting one. Based on the task analysis data, AFHRL/OT would first need to determine what types of performance data are actually necessary to collect. Then it would be necessary to determine the feasibility of embedding the desired features for adequate performance measurement in the host equipment in terms of costs and training effectiveness trade-offs.

In a similar manner, AFHRL/ID could determine what performance measures are required for general purpose computer systems, then include the appropriate performance measures in embedded AI job aids for applications programs.

Potential Customer: The level of performance measurement in most embedded training systems currently in use varies considerably. ASD/ENE (Directorate of Support Systems Engineering) has requested that research be undertaken in the area of embedded training performance assessment. Similar needs exist at the SSC to link on-the-job performance with on-the-job training in general computer software applications. Our study has indicated that there is little "hard" evidence (i.e., performance measurement data) for claims of improved operational readiness due to embedded training. Research into performance measurement requirements for embedded training can provide both the information required to design more effective systems, and to assess force readiness at a very discrete level. Performance measurement data can be useful at the lowest echelons in the operational command in identifying operators who require additional training or practice, and exactly what areas these individuals need practice in. At MAJCOM levels, performance measurement data can be accumulated to pinpoint weaker units for more training emphasis or other assistance, to identify stronger units for rewards, and to assess the overall ability of the command to carry out its mission.

Relevant AFHRL Strengths: AFHRL/ID has developed performance measures for training effectiveness evaluation; AFHRL/LR has focused its efforts specifically on the evaluation of C^2 skills; and, AFHRL/OT has concentrated on performance measurement for aircrew training.

Risks: Performance measurement in anything other than a training environment is traditionally looked upon as a threat. This is particularly true when the performance measurement system judges how well someone does his job. Although performance measurement is frequently considered to be a "good" feature of embedded training systems, it still must gather the right kinds of information, assess it, and make proper use of it. Major command support may be difficult to obtain unless increased operational readiness can be shown as a result.

Embedded Training within the Total Training System

Technology Development Area: Considerations of embedded training usually are not incorporated into total training systems planning. The occurrence of embedded training in systems seems to have been the result of engineers trying to incorporate a means for operators to practice using the system. If one starts to think about embedded training during systems development, one is too late to affect the configurations of either the system or the training for the system. The selection of embedded training as a training medium and the determination of what embedded training features to include should be a part of the system concept. They should be included in training planning from the very first steps of the system specification and design process.

It is clear that embedded training should be considered within the context of a total training system approach. The question is: Where does it fit in? AFHRL/LR's contacts at AFSPACECOM would be needed to set up a project which assessed the entire spectrum of Space Training, including embedded training. The necessary research would probably involve an analysis of the media characteristics of embedded training (i.e., its various features). Some of these features could be incorporated into an existing system and their effect on the training system assessed. This type of project would probably best be undertaken *after* some earlier "groundwork" research on embedded training had been done, and there was more widespread recognition of the roles of embedded training. This work could probably draw from and build on ARI's project on "Embedded Training Utilization Tools" (scheduled for completion in Fiscal Year 1992).

The discussion above concentrates on existing embedded training systems. A similar project could also be undertaken with a new developing system. The more likely customers in that case would be ASD for airborne systems and ESD for electronic systems. In either event, the impact of embedding training into a new system versus into an existing system might provide an interesting contrast for research.

Potential Customer: AFSPACECOM and ESD have a number of existing fielded systems which could benefit from embedded training research. BMEWS, PAVE PAWS and other similar systems have been using embedded training since their fieldings; however, the impact of these embedded training systems on what needs to be taught in formal classroom training or on the total training system has not been examined. AFSPACECOM has had a persistent problem when it comes to the total training picture. AFSPACECOM has numerous different kinds of systems at multiple sites worldwide for which skilled operators must be prepared. "Generic" training at a central facility does not always provide the needed training for operators. Without some kind of embedded training for these systems, AFSPACECOM has no effective way of dealing with this problem. In addition, ESD program managers, particularly newly assigned ones without the benefit of experience in developing systems, have no basis for selecting the proper embedded training features. Assistance is needed for them in assessing the impacts of embedded training on the acquisition and development of systems.

Relevant AFHRL Strengths: AFHRL/MO's MPT program is particularly relevant in assessing total training requirements. The concept behind AFHRL/LR's Concurrent Engineering work is also applicable to a project for determining total training requirements for a system. AFHRL/LR's contacts with AFSPACECOM would be beneficial in setting up any program with them.

Risks: There is a risk that without the proper kinds of guidelines, embedded training will be selected for training when it is inappropriate or that it may *not* be selected for training when it is the *most* appropriate medium. Even more likely is the problem of identifying the required embedded training features for a system early enough in the acquisition and development process.

Determining Costs of Embedded Training

Technology Development Area: AFHRL could gather cost data from a wide variety of existing embedded training systems (the systems identified in Appendix A of this report could be a start). It would probably be necessary to work closely with the system program managers (perhaps through ESD) to sort out the specific costs of the embedded training component, including the exact sources of the costs. We would suppose that system stimulation might be a low-cost item for most signal processing systems. Some embedded training features which may contribute to increased cost may include making scenario production user-friendly for supervisors; the transportability of scenarios from one system/site to another; mixing simulated and live signals (or the suppression of one or the other); and the capability to conduct multi-site training.

This issue goes hand-in-hand with determining training effectiveness. The costs of adding an embedded training component (or specific embedded training features) to a computerized system must be one of the considerations in determining the appropriate media.

Ideally, this project would result in some kind of automated tool which would allow training planners or program managers to assess the cost and safety trade-offs that might result from their decision to add a particular embedded training capability to a system. AFHRL could probably build upon the work conducted by ASD/XR on Automated Training Projection Methodologies (O'Brien & Hess, 1988c). However, unlike the ASD/XR effort, AFHRL's work should be based upon and incorporate a significant amount of foundational research on embedded training.

Potential Customer: Our study showed that most people are unaware to what extent embedded training adds to the cost of a computerized system. These individuals are also unaware of the various types of embedded training features which are available for them to use in designing the specific embedded training component of their system, and of the degree of difficulty associated with developing each. ESD program managers are not accustomed to dealing with training, let alone how various embedded training features can be used to address the specific training requirements of a large computerized system. Therefore, the program managers are not in the habit of estimating the impact of various embedded training features either on the technology of the system being developed or on its costs. The determination of some basic embedded training cost factors and a decision aid to help program managers are needed by ESD.

Relevant AFHRL Strengths: AFHRL/ID's work on the Training Decisions System (TDS) has shown that it is clearly capable of dealing with training cost data. AFHRL appears to have a strong commitment to providing Air Force customers with decision aiding tools, as evidenced by AFHRL/ID's involvement in TDS, and AFHRL/LR's involvement in CAD/CAE design tools. A similar decision aid for embedded training would be very consistent with these activities.

Risks: The risks of such a study could be minimized if it were performed in conjunction with other embedded training research efforts. The only obstacle is that in order for the study to be performed, AFHRL will have to work with cost data which have traditionally not been itemized in budgets for systems. AFHRL would need the system program managers' cooperation

plus some technical expertise to sort out which budget items relate to the embedded training component, and to what extent various embedded training features add to the cost of the system.

Model Specifications for Embedded Training

Technology Development Area: Embedded training systems tend to vary widely, and the features found from one embedded training system to the next are not standardized. Guidelines for the development of embedded training could contribute to the standardization of embedded training features across similar systems.

This R&D should be the culmination of earlier research on embedded training. To be maximally useful, the study should probably result in some type of automated decision aid which would (a) allow training planners to see the effect of decisions they make with regard to embedded training, in terms of cost and effect on the host equipment; and (b) produce some kind of "boilerplate" which could be tailored for embedded training specifications based on inputs to the decision aid. The lead AFHRL division for this R&D effort could be either AFHRL/LR or AFHRL/OT, depending on whether the customer was ESD (concerned with electronic systems) or ASD (concerned with aircraft systems).

Potential Customer: Both ESD and ASD need assistance in properly defining the required embedded training features for systems they are acquiring or developing. Program managers in these organizations are unaware of embedded training and its impact on computerized systems.

Relevant AFHRL Strengths: Much of AFHRL's work has been oriented toward helping the Air Force be a "smart shopper" through the development of "model" specifications for systems. AFHRL is certainly familiar with specifications development. Some training systems for which AFHRL has been involved in specifications development include the C-130 Model Aircrew Training System and the B-52/KC-135 Combat Crew Training System (CCTS) Modernization (AFHRL/OT), and Command and Control Team Training (AFHRL/LR). Although none of these are embedded training systems, they still demonstrate AFHRL's overall sensitivity to training needs and issues through the development of model specifications. AFHRL/ID's experience in developing decision aids for training planners should also be very useful.

Risks: There is a risk that the computerized weapon systems selected to model may be designed with embedded training in mind, that the embedded training component of the system will become a driving factor in system design and development rather than be a part of the total training package for the weapon system. Embedded training should never be forced on a system. The possibility for failure is high if the embedded training does not properly "fit" the weapon system. For example, the Training Interface Unit (TIU), an embedded training component of the Army's "Aquila" Remotely Piloted Vehicle, was intended to train system operators in flying skills, payload operations, and engaging targets; however, according to Army sources, the TIU had only limited usefulness because its portrayal of targets and artillery bursts lacked realism.

Potential R&D Agenda

As a result of having identified many of the issues facing embedded training designers, developers, and users during this study, we have suggested some potential R&D technology development areas that AFHRL can explore in meeting the Air Force's needs for embedded training. Now, we will outline ways for AFHRL to accomplish this task (i.e., an embedded

training R&D strategy for AFHRL). The proposed embedded training R&D agenda is summarized in Table 2 and provides a basis for identifying AFHRL's role.

Table 2. **AFHRL Potential R&D Agenda**

Technology area	**Potential project**	**Potential customers**
1. Safety of ET	Characterization of Existing ET Features	AFSPACECOM
	Airborne ET	ASD
2. Intelligent Tutors for Standard Systems	ET for Financial Applications	A&F Center
	AI Aids for Application Software Training	SSC
3. Embedded Performance Measurement and ET	Airborne ET	ASD
	ET in Standard Systems	SSC
4. ET in Total Training Systems	Determination of ET Features	AFSPACECOM
5. ET Costs	Cost Effectiveness of ET Features	ESD
	ET Decision Aid	ESD
6. Model ET Specifications	Model Specs for Airborne Systems	ASD
	Model Specs for Radar Systems	ESD, AFSPACECOM
	ET Decision Aid	ASD, ESD

Implementation Strategies

Joint Service Activities

If AFHRL decides to become more involved in embedded training R&D, we would recommend that it also become actively involved in the JTCG-TSD Embedded Training Working Group. To our understanding, AFHRL/OT is AFHRL's representative on the JTCG-TSD. However, the degree of participation by that division has been limited.

We would also recommend that the Air Force follow its own R&D agenda rather than simply adopting what has been proposed by the JTCG-TSD. There are two reasons for this. First, the Air Force has some distinctly different needs, weapon systems, training requirements, and

procurement policies from those of the other Services. Therefore JTCG-TSD products like ARI's 10-volume set of *Guidelines for Implementing Embedded Training* will need further modification before they can fully address Air Force concerns, or before they can be used by Air Force customers. The Air Force needs research products which directly address Air Force needs.

Second, and perhaps more importantly, the other Services are pursuing embedded training research projects even as they increase their use of embedded training. Both the Army and Navy already promote and widely use embedded training. The other Services already have in place policies concerning the consideration of embedded training as a medium and policies for its use. Both the Army and Navy apparently have no problem in selecting embedded training as a medium or in developing embedded training systems. In contrast, Air Force users and potential users of embedded training appear to be more cautious, and will probably require more research in support of embedded training before they are willing to endorse its use. We believe that the Air Force needs to pursue a step-by-step strategy of conducting embedded training research which eventually culminates in the development of guidelines for the acquisition and development of embedded training prior to its extensive use throughout the force.

Projects, Customers, and Resources

Three AFHRL Divisions have a high potential for effectively engaging in embedded training R&D: the Operations Training Division (AFHRL/OT), the Training Systems Division (AFHRL/ID), and the Logistics and Human Factors Division (AFHRL/LR). Each of these Divisions has unique capacities which allow it to perform specific embedded training R&D. These capacities and the potential for embedded training R&D associated with each are summarized below.

The Operations Training Division (AFHRL/OT):

Projects: The potential for embedded training aboard aircraft remains high on the list of R&D issues to be explored. However, there will be relatively little payoff in the near term for projects supporting ASD's embedded training needs. ASD's concerns focus on the safety of embedded training. Of all the Laboratory divisions, we feel that AFHRL/OT can best support ASD in finding a solution to its embedded training R&D problems.

Customer: ASD/ENE has already shown an interest in OT's assisting with embedded training R&D. If AFHRL is interested in supporting the flying MAJCOMs through embedded training R&D, it will have to market other segments within ASD (namely the SPOs), and gain the interest of SAC, TAC, and MAC.

Equipment: Some use could probably be made of AFHRL/OT's existing simulator capability. In addition, ASD/ENE could probably identify a candidate aircraft (or avionics subsystem) to serve as a testbed for embedded training research (e.g., the ATF program).

Personnel: AFHRL/OT has an appropriate mix of professional staff and contractors to support aircraft embedded training R&D. Technical skills in aircrew training and complementary engineering skills provide the right combination for embedded training R&D to be successful.

The Training Systems Division (AFHRL/ID):

Projects: Based on AFHRL/ID's past track record, the AI projects proposed in this report are highly likely to succeed if undertaken by that division. The definite but unrecognized need

for embedded training assistance by the SSC could produce several projects if marketed properly. AFHRL/ID must work hard to gain support from SSC for any embedded training research task. However, once the SSC has seen the benefits to be derived from embedded training, they should become a much more willing customer. AFHRL/ID could also build on its research in Job Performance Measurement (JPM). AFHRL/ID's JPM and AI capabilities combine to provide the Laboratory with a unique opportunity to assist SSC with some of its more difficult software training problems.

Customer: The critical problem facing AFHRL/ID is to market a customer for its potential embedded training R&D products. As we see it, the most likely potential customer for AFHRL/ID is the SSC. However, SSC has not recognized embedded training as a potential solution to their problems and will need to be sold on it. When approaching SSC, ID might well focus on solving SSC's training problems rather than on "selling" embedded training.

Equipment: AI development platforms and the appropriate software tools will be needed for any embedded training project using AI in support of the SSC. The source codes for one or more standard systems, programmers who understand them, and the appropriate computer hardware will also be required.

Personnel: Marketing skills in the person selected to head up this embedded training effort will be essential to its success. No projects have been proposed by the potential customer. SSC currently feels that they are able to do it themselves. Anyone approaching SSC must be able to convince them that they need the research.

The Logistics and Human Factors Division (AFHRL/LR):

Projects: Several AFSPACECOM projects were suggested which take advantage of the existing skills in this division. Most of these projects will likely have a relatively shorter-term duration (i.e., 2 to 3 years) and only a moderate risk factor. We feel that AFHRL/LR can best support AFSPACECOM's training needs. AFHRL/LR can also provide needed support to ESD program managers in recognizing requirements for embedded training and being able to cost-effectively select the proper embedded training features necessary for a system.

Customer: AFSPACECOM has already expressed an interest in working with AFHRL. The critical factor in engaging in embedded training R&D with AFSPACECOM is to approach them with the intention of improving their overall training and readiness posture. ESD must be marketed as a potential customer. There is a greater likelihood of success at ESD because of the direct connection with AFSPACECOM systems.

Equipment: Any work done will have to be compatible with existing AFSPACECOM systems. This may entail having a similar computer architecture set up as a testbed for AFHRL/LR or being associated with the contractor developing an AFSPACECOM system.

Personnel: AFHRL/LRG (the Laboratory branch with the strongest contacts at AFSPACECOM) has its current staff resources spread across several projects. This could pose a serious problem in taking on any additional work in support of embedded training R&D.

Commitment and Leadership

In order to undertake embedded training research, the management of AFHRL must make a positive commitment to doing so. In each of the cases described in this study, we have pointed out the strong necessity for the division involved to be able to market their capabilities to potential customer(s). The Laboratory must also commit to designating and supporting

someone within AFHRL as the focal point for embedded training R&D. This individual does not have to be proficient in embedded training design or development, but he or she should be well respected technically and have an insight into training problems and their potential solutions. The Laboratory's focal point for embedded training should also be appointed to the Joint Technical Coordinating Group's Embedded Training Working Group.

In our opinion, one of the keys to the success of the AFHRL embedded training R&D agenda is performing some embedded training R&D task as soon as possible to solidify the Laboratory's credibility in the field. The Laboratory's Commander may need to exert personal influence to market potential customers and inaugurate an initial embedded training task.

Our initial concept was that a single AFHRL division should take the lead in embedded training R&D to the exclusion of the other divisions. We have modified our position somewhat based on the potential customers and the relationships already established with them by some of the divisions. We now feel that AFHRL/LR appears to have the greatest probability of being able to obtain and sustain support for its embedded training R&D tasks. However, we also feel that each division should pursue one or two embedded training customers. AFHRL/OT should concentrate initially on ASD and, then, on the CONUS flying commands. AFHRL/ID should try to capitalize on its decision aiding and AI expertise by focusing on the SSC. In general, initial research should focus on the issues described in this study, then branch out as the customer becomes more accustomed to dealing with embedded training.

APPENDIX A: EMBEDDED TRAINING SYSTEMS

Air Force Embedded Training Systems

AMHS - Automated Message Handling System [proposed]

ATF - Advanced Tactical Fighter [proposed]

AWACS - Airborne Warning and Control System

BCAS - Base Contracting Automated System

BMEWS - Ballistic Missile Early Warning System

CAMS - Core Automated Maintenance System [proposed]

CAS - Combat Ammunition System

CBTS - Computerized Base-level Training System

CMOS - Cargo Movement System [proposed]

COOF - Comptroller Office of the Future Embedded Training [proposed]

Embedded Training for Tactical Aircraft Project

F-16 OBEWS - F-16 On-Board Electronic Warfare System

GPMCS - Global Positioning System Master Control Station

IBM 4381, CPCI-235 module

MPRS - Medical Personnel Records System

OBS F-15 - On-Board Simulation System

OTH-B - Over-the-Horizon Backscatter Radar [proposed]

PACCITS - PACAF Command & Control Info. & Training Sys. [proposed]

PAVE PAWS - PAVE Phased Array Warning System

SRS - Satellite Readout Station

TEMPLAR Embedded Training [proposed]

WWMCCS - Worldwide Military Command and Control System

Army Embedded Training Systems

AFATDS - Advanced Tactical Data System

AN/TPQ-29 - Hawk Missile System Radar Signal Stimulator

AN/TSQ-73 - Missile Minder Command and Control System

FAAD NLOS - Forward Area Air Defense Non Line of Sight

FOQ-M - Fiber Optic Guided Missile

HIP - Howitzer Improvement Program

MCS 2 - Maneuver Control System 2

MLRS - Multiple Launch Rocket System

Patriot Missile System Embedded Training

TACFIRE - Tactical Fire Direction System

TIU - Training Interface Unit

Navy Embedded Training Systems

ACTS - Aegis Combat Training System

ADSIM - Automatic Detection Tracking System Simulation

ADTSM - Automatic Detection and Tracking Simulator

AN/BSY-2 - Combat Control Onboard Training

AN/SQQ-89 - Surface Anti-Submarie Warfare (ASW) Combat System

AN/SQR-OBT

AN/SQS-56 Target Simulator

AN/SQS-T5

CATCC STSS - Carrier Air Control Ctr. Shipboard Simulation Sys

CSTS - Combat Simulation Test System

CSTS - Combat System Test Set

CTORP - Combat Team Operational Readiness Program

DPT - Deployable Proficiency Trainer

ECM - Electronic Counter Measures Generator

GMTR - Guided Missile Training Round

Guided Missile Simulator, MK 89 MOD0

IFT - In Flight Training System

L-TRAN - Lesson Translator

LHD-1 CSTS - Combat Simulation Test System, AN/SSQ-91

ORATS - Operational Readiness Assessment and Training System

OSMOS - Own Ship Motion Simulator

OTS - Operational Training Software for SLQ-32

PME - Performance Measurement and Evaluation for Sonar

PME - Performance Measuring Equipment for SQQ-23

RACOR - Radar Recorder

Navy Embedded Training Systems (Concluded)

Radar Proficiency Simulator

RAVIR/MCST - Radar Video Recorder/T-3 Mobile Combat Systems Trainer

REES-204 - Radar Electromagnetic Environmental Simulator

RESS - Radar Environmental Simulator System, AN/USQ-93

RFTT - Radio Frequency Target Generator

RVS - Radar Video Simulator

SEAT - System Evaluator, Trainer, MK 16 MOD 1

SETS - SPA -25G Embedded Training System

Silverbox 2/WLR-1

SORATS - Submarine Operational Readiness Assessment and Training System

STSS - Sonar Target Signal Simulator

STTP - Simulated Target Training Program

Tactical Modular Display

TM CCS - Training Mode of Combat Control System

TTP - Tactical Proficiency Program

TSAM - Training Surface to Air Missile

Unit 34, Sonar Target Generator

VSSG VSS-SM 319A - Video Signals Simulator

APPENDIX B: EMBEDDED TRAINING TELEPHONE QUESTIONNAIRE

Instructions:

Please provide as much of the following information as possible regarding the designated Embedded Training (ET) system. If you are unable to answer the question or to provide any data, indicate such and provide a reason (e.g., Not Available, Classified, etc.). If you have more data than can easily be transcribed on the form, please attach whatever documentation you feel is pertinent. Feel free to indicate the name(s) and contact phone (commercial and AUTOVON) or personnel who may be a source of additional details:

Section I - System Descriptive Information

1. ET system name:
2. ET system developer:
3. Host system name (if different from ET System):
4. Host system developer:
5. Platform:
6. Sponsor Organization:
7. ET added before/after host system became operational?
8. Does the ET require the use of additional special equipment? If so, please describe. ______________________________

____

____

9. On a scale of 1 to 5, indicate the degree to which each of the following factors influenced the selection of ET as a training medium (1 = little or no influence; 5 = great influence; DK = don't know).

a.	Internal policy requirements	1	2	3	4	5	DK
b.	Availability of operator slack time	1	2	3	4	5	DK
c.	Dispersed location of trainees	1	2	3	4	5	DK
d.	Cost benefits	1	2	3	4	5	DK
e.	Security	1	2	3	4	5	DK
f.	Need to make training available to reservists or other "part-time" personnel	1	2	3	4	5	DK
g.	Need for operator refresher training	1	2	3	4	5	DK
h.	Media selection process	1	2	3	4	5	DK
i.	Other ______________________________	1	2	3	4	5	DK

____

____

10. On a scale of 1 to 5, indicate to what extent each of the following was used in development of the embedded training (1 = not used; 5 = much used; DK = don't know).

a. Job/Task Analysis	1	2	3	4	5	DK
b. Training Objectives	1	2	3	4	5	DK
c. Host System documentation	1	2	3	4	5	DK
d. Host System developers' advice	1	2	3	4	5	DK
e. Other ______________________	1	2	3	4	5	DK

____

____

If any of the above were used, please attach a copy, if available.

Section II - ET System Training Information

11. What skills is the system intended to teach? ______________________

____

____

12. What kind of training goes on? (check all that apply)

a.	[ ] Basic/Entry	[ ] Continuation	[ ] Upgrade
b.	[ ] Individual	[ ] Team	[ ] Sub-team
c.	[ ] Operator	[ ] Maintenance	
d.	[ ] Complete scenario	[ ] Specific Function(s)	

13. Please indicate specialty of personnel being trained on this system. Use specialty codes (i.e., AFSC, MOS, NEC) if possible.

____

____

14. Is user documentation available? [ ] Yes [ ] No [ ] DK
If yes, which of the following does it include?
Please check all that apply.

[ ] Installation and set-up instructions
[ ] Instructional guidance
[ ] Training objectives
[ ] Help screens
[ ] Other (please describe):

____

____

____

15. Are on-line scenarios available? [ ] Yes [ ] No [ ] DK
If yes, which of the following features are available?
Please check all that apply.

[ ] Scenario authoring capability
[ ] Canned scenarios
[ ] Pause capability
[ ] Fast forward capability
[ ] Other (please describe):

____

____

____

16. Is student performance recorded? [ ] Yes [ ] No [ ] DK
If yes, which of the following features are available?
Please check all that apply.

[ ] Playback of students' sessions
[ ] Storage of student performance records
[ ] Other (please describe):

____

____

____

17. Is on-line feedback available? [ ] Yes [ ] No [ ] DK
If yes, which of the following features are available?
Please check all that apply.

[ ] Diagnostic feedback
[ ] On-line remediation
[ ] Other (please describe):

____

____

____

18. Development status of the ET:
Drawing board [ ] Prototyped [ ] In testing [ ] Fielded [ ]

If in testing or already fielded, complete Section III; otherwise skip to Section IV.

Section III - System Usage Information

A. Deployment sites

19. Describe the types of sites where the ET system has been deployed:

____

____

20. List the sites where the ET system is being deployed at present:

____

____

____

21.
How many and where are future sites for deployment? ____________

____

____

B. Frequency of use

22. Please estimate how many people are using this ET system at present (e.g., # per month/year, etc.): ____________________

23. On a scale of 1 to 5, how would you characterize the extent of actual use of this system in the field (1 = seldom or never used; 5 = very frequently used)? 1 2 3 4 5

If the answer to question 23 is 1, 2, or 3, then complete question 24; otherwise skip to question 25.

24. On a scale of 1 to 5, indicate the degree to which each of the following factors may have contributed to the system's not being more frequently used (1 = not a factor; 5 = major factor; DK = don't know).

a. System is inoperative while ET is in use	1	2	3	4	5	DK
b. ET updates lag behind host system updates	1	2	3	4	5	DK
c. ET documentation is insufficient/ unclear	1	2	3	4	5	DK
d. ET is inconvenient to set up or use.	1	2	3	4	5	DK
e. ET is frequently down or bug-prone	1	2	3	4	5	DK
f. Other____________________ ____________________	1	2	3	4	5	DK

25. Has the effectiveness of the ET been assessed?
[ ] Yes [ ] No [ ] DK
If yes,

a. Who performed the assessment?

b. Were the results positive or negative?

c. Has the assessment had any effect on modifications to the ET system?

Please provide a point of contact for this information (use pg. 6); and attach a copy of the data, if available.

Section IV - Other

26. If you wish, you may use the space below to make other comments about this ET system.

27. How could the ET be improved?

Section V - Recommended Contacts

Please recommend any points of contact who you think would be helpful.

Name:
Phone:
Organization/Company:
Function (e.g., developed ET, program manager, etc.):

Name:
Phone:
Organization/Company:
Function (e.g., developed ET, program manager, etc.):

Name:
Phone:
Organization/Company:
Function (e.g., developed ET, program manager, etc.):

Name:
Phone:
Organization/Company:
Function (e.g., developed ET, program manager, etc.:

The responses to this inquiry will be used in statistical analyses across systems, and will not be released other th-' to AFHRL/SA without prior permission o. .e respondent.

APPENDIX C: INFORMATION TO BE GATHERED DURING SITE VISITS

Overview

The purpose of the site visits is to gather information about particular embedded training (ET) systems which will aid in the development of R&D strategies in ET for AFHRL. Information will be gathered in the following categories:

- General Information
- Cost of ET
- Responsibility for ET
- Resistance to ET
- Evaluation of ET
- ET Development Milestones
- Skills Taught via ET
- Instructional Range of ET
- Operational Features of ET
- ET System Architecture
- User Manuals for ET
- ET System Maintenance
- Trainees' Response to ET
- Training Supervisors' Response to ET
- Scheduling Use of ET

The following section describes in detail the type of information desired in each category.

Detailed Description

General Information

Information desired: Name of host system; name of ET system (if different from host); platform; interviewees' names, job titles, and organizational affiliation.

Cost of ET

Information desired: Cost of the ET; cost calculation methods or tools used; use or non-use of cost-effectiveness analyses in selection of ET as a training medium.

Responsibility for ET

Information desired: Names of contractors and in-house organizations responsible for the ET, their roles, and qualifications. Were roles clearly delineated? How was role confusion resolved? How was responsibility for training transferred to ATC or to field training supervisors after the system was fielded?

Resistance to ET

Information desired: Sources of resistance, if any, to the use of ET and their concerns; ways these concerns were resolved. What types of information or data would have helped to alleviate these concerns?

Evaluation of ET

Information desired: Methods used to evaluate the instructional effectiveness of the ET; methods for data collection and analysis; evaluation results; evaluation scheduling; provisions for making changes based on evaluation results.

ET Development Milestones

Information desired: Description of what was presented for ET at each milestone of the host system development cycle. To what extent was ET an item for discussion at Air Force Systems Acquisition Review Council (AF SARC) meetings?

Skills Taught via ET

Information desired: Skill areas taught by the ET; specific procedures or factors used to select skill areas to be taught by the ET. Were task analyses utilized in making these decisions? Were desired skill areas prioritized?

Instructional Range of ET

Information desired: Role of ET in the total training pipeline for the trainee. Which of R. Gagne's nine events of instruction are provided by the ET and which are provided for by other forms of training (see attached list of R. Gagne's nine events of instruction)? Is it necessary or desirable to use ET for all instructional events?

Operational Features of ET

Information desired: Description of features offered by the ET, such as rewind, fast forward, freeze, scenario authoring, performance recording, and feedback; most commonly used features; desired features. For performance recording, exactly which aspects of student performance are recorded? For feedback, is the feedback tailored to student responses or just correct/incorrect?

ET System Architecture

Information desired: Techniques used to add ET to the host system; extent to which ET data are handled differently from real data; extent to which system architecture was influenced by training requirements.

User Manuals for ET

Information desired: Description of manuals developed to guide ET set-up, operation, or use in training. How is this documentation made available to supervisors and trainees using the system? Which manuals are most commonly used?

ET System Maintenance

Information desired: Procedures for managing malfunctions in or updates to the ET system. How is the cost of maintenance accounted for?

Trainees' Response to ET

Information desired: Description of trainees' reactions to ET and problems they have experienced with the system.

Training Supervisors' Response to ET

Information desired: Description of training supervisors' reactions to ET; problems experienced in using ET for training (e.g., problems with system unavailability or instructional inadequacy). What features have they commented on?

Scheduling Use of ET

Information desired: Typical scheduling of ET use on a daily basis. Is use of ET considered to be training or time on the job?

Summary

The interviewer may structure the site visit in any appropriate manner, but should focus on gathering information in the 15 categories described above for each ET system being studied. In some cases, obtaining the desired information may require interviewing representatives from different offices. The interviewer should keep a record of the source of each item of information obtained.

APPENDIX D: ANNOTATED BIBLIOGRAPHY

Battle, V.M. (1987). *AN/BSY-2 combat control onboard training: Concept of operations.* Newport, RI: Naval Sea Systems Command.

Presents overview of AN/BSY-2 onboard training (OBT) function, including a description of the role of the OBT exercise controller, the OBT mode requirements, and information on the OBT database. The specific functional requirements for the combat control OBT are also addressed.

Beyers, D. (1988). Embedded training: Getting closer. *Military Forum,* 4(9), 56-59, 62-63.

Article of general interest about the use of embedded training in the Military Services.

Carroll, R.J., Roth, J.T., Evans, D.C., & Ditzian, J.L. (1988). *Implementing embedded training: Volume 10 of 10. Integrating ET into acquisition documentation.* Alexandria, VA: Army Research Institute.

Provides guidelines as to which volumes are to be used in preparing specific acquisition documents, and guidance in preparing procurement documentation.

Cherry, W.P., Peckham, D.S., Purifoy, G.R., & Roth, J.T. (1988). *Implementing embedded training: Volume 9 of 10. Logistics implications.* Alexandria, VA: Army Research Institute.

Provides guidance on logistics issues, and assists in defining the support requirements imposed on the prime system due to inclusion and integration of ET.

Collins, A., Warnock, E.H., & Passafiume, J.J. (1975). Analysis and synthesis of tutorial dialogues. In G.H. Bower (Ed.), *The psychology of learning and motivation* (Vol. 9, pp. 49-87). New York: Academic Press.

Describes some of BBN Laboratories, Inc.'s early work on intelligent tutoring systems development.

Davis, J.A., Eckel, J.S., Rabeler, S.W., Dobbins, F.W., Gorg, F.A., McNeley, T.L., & Hurst, K.L. (1986). *Embedded training concepts evaluation* (ASD-TR-87-5017). Wright-Patterson AFB, OH: Aeronautical Systems Division.

Provides results of a concept design and evaluation study which examines the tactical fighter aircraft. Presents two designs to implement ET on a current configuration and emerging configuration of the F-16. Evaluates the two design concepts in an air-to-ground simulation environment, and projects cost and design, and performance impacts of the design concepts.

Downes-Martin, S., Harris, M., Kurland, L., & Massey D. (1986). *Embedded training technology survey.* Cambridge, MA: BBN Laboratories, Inc.

Presents an ET design methodology which focuses on the factors most important for technology selection. Six areas of technology are reviewed and evaluated: computer-generated imagery, image storage and retrieval, speech synthesis, speech recognition, symbolic processing, and large-scale digital storage. Also presents procedures useful for guiding developers in establishing requirements and designs for ET.

Eagle Technology. *Embedded training support tools: Characteristics which constrain embedded training* (TR #836.02-1). Arlington, VA: Eagle Technology.

Provides a background of various considerations for implementing ET into systems, and for defining the system requirements and constraints. These factors are broken down into three classes: engineering, operational, and environmental characteristics.

Evans, D., Adams, J., Simkins, M.L., Aldrich, R.E., Dyer, F., & Narva, M. (1988). *Lessons learned from ET design process for ASAS/ENSCE* (ARI Research Note 88-87). Alexandria, VA: U.S. Army Research Institute.

Takes both the Army's ASAS and the Air Force's ENSCE ET programs and evaluates them by task analysis, ET requirements selection and ET system design and integration, thereby providing insight to lessons learned. The report also includes the development and evaluation of procedures and guidelines for targeting ET needs and implementing ET

Evans, S.M., & Cherry, W.P. (1988). *Implementing embedded training : Volume 6 of 10. Integrating ET with the prime system*. Alexandria, VA : Army Research Institute.

Provides guidelines for effective integration of ET into the design of the system.

Finley, D.L., Alderman, I.N., Peckham, D.S., & Strasel, H.C. (1988). *Implementing embedded training: Volume 1 of 10. Overview* (ARI Research Product 88-12). Alexandria, VA: U.S. Army Research Institute.

Presents an overall view of 10 volumes to be used as guidance documents when implementing ET, including their contents, purposes, and applications.

Gershanoff, H. (1989). A range in a pod: Bringing EW training to the squadrons. *Journal of Electronic Defense*, 12(5), 57-59, 69.

Discusses the on-board electronic warfare simulator (OBEWS) in detail, including hardware components, system operation, debriefing after landing, and criticisms of the OBEWS system. Also addressed is the need for more electronic warfare training.

Hendrix, J.H. (1989). Embedded training: proper requirements analysis ensures quality. *Proceedings of the 11th Interservice-Industry Training Systems Conference* (pp. 253-258). Arlington, VA: American Defense Preparedness Association.

Provides candidate criteria to determine ET requirements, discusses how technology advances will enhance ET, and reports on the interfacing of the tactical hardware and software and the ET software.

Hoskin, B.J., Jorgensen, W.F., & Manglass, D.A. (1988). *Lessons learned from currently fielded Navy embedded training systems*. Orlando, FL: Naval Training Systems Center.

Provides an evaluation of ET designs of already fielded ET systems in order to develop a set of guidelines for the design of future ET capabilities. Also consolidates lessons learned with regard to the systems designs, capabilities, and their effectiveness for training.

Jorgensen, W.F. (1986). *Feasibility report and embedded training system features selection process for AN/SPA-25G embedded training* (Contract No. DAAG29-81-D-0100). Winter Park, FL: Eagle Technology.

Provides general data concerning costing issues for ET instructional features, including descriptions of the purpose, operational aspects, and technical requirements. The report also discusses the combination of requirements which lead to complete scenario development.

Jorgensen, W.F. (1987). *Training effectiveness and evaluation report for the AN/SPA-25G embedded training scenario concepts* (Contract No. DAAG29-81-D- 0100). Winter Park, FL: Eagle Technology.

Provides for an estimate of the effectiveness of training features when evaluated by operational personnel familiar with the system. Also recommends features to be implemented in a developmental training system.

Jorgensen, W.F., Hoskin, B.J., & Manglass, D.A. (1988). *AIC critical subtask and equipment proficiency training report*. Winter Park, FL: Eagle Technology, Inc.

Documents the technical approach and activities performed in developing the critical subtask, equipment proficiency, and air intercept control (AIC) full mission scenarios for the AN/SPA-25G Embedded Training System (SETS).

Jorgensen, W.F., & Muse, K. (1986). *Research plan for AN/SPA-25G embedded training* (E-Tech TR-5938-3). Winter Park, FL: Eagle Technology.

Presents four phases to the research plan including development of selection criteria, selection of required features, specification of the features prototype implementation, and test and evaluation of the prototype. All phases provide specification for which instructional features must be included in ET to ensure success.

Killion, T.H. (1986). *Electronic combat range training effectiveness* (AFHRL-TR-86-9, AD-B104 833L). Williams AFB, AZ: Operations Training Division, Air Force Human Resources Laboratory.

Presents experiments which examine effects of real-time and post-mission feedback capabilities on the effectiveness of electronic combat training systems. Identifies and demonstrates cost-effective simulator training strategies and systems to develop and maintain the combat effectiveness of aircrew members.

Leishman, S.A. (1989). *Embedded training design considerations. Proceedings of the 11th Interservice-Industry Training Systems Conference* (pp. 544-552). Arlington, VA: American Defense Preparedness Association.

Provides a brief history of ET, information about training as it applies to ET, potential ET roles, reasons to use ET and potential benefits, disadvantages of using ET, design considerations, and hardware and software requirements.

Lieb, J.C. (1989). *On-Board electronic warfare simulator (OBEWS) IOT&E test plan.* Eglin AFB, FL: USAF Tactical Air Warfare Center.

Presents a plan for an operational test and evaluation of the on-board electronic warfare simulator. Provides an evaluation of the OBEWS operational effectiveness and stability as a training device, and identifies any operational deficiencies. Areas covered in the report

include objectives and methodology, management, resources and responsibilities, and administration.

Malehorn, M.K. (1985a). *Evaluating the requirement for exploratory development on embedded training: Volume I. Source materials* (E-Tech TR-5881-1). Arlington, VA: Eagle Technology.

Provides a program to develop a procedure for the examination of ET in order to determine the merit (whether to fund, and how much) of the shortfalls of ET as a subject for research and development.

Malehorn, M.K. (1985b). *Evaluating the requirement for exploratory development on embedded training: Volume II. Defining payoff characteristics and data requirements* (E-Tech TR-5881-2). Arlington, VA: Eagle Technology.

Provides a description of the analytical procedure required in decision making concerning an exploratory development program involving personnel, training, human factors, and simulation. Includes the requirement for analysis, payoff, and measuring payoff, with the objective being to realistically define payoffs of projects being reviewed.

Malehorn, M.K. (1986). Embedded training in naval environments: Current and future state (E-Tech TR-5938-1). Arlington, VA: Eagle Technology.

Provides a review of the literature, a point paper, key research topics, key user acceptance issues, research methodologies, and milestones and resources. Provides a timeline for research on ET and an estimate of resources required. Also reports three variables to be considered when attempting to fully realize the potential of ET. These include acquisition, employment, and training characteristics of ET.

Massey, D., Harris, M., Downes-Martin, S., & Kurland, L. (1986). *Embedded training technology survey.* Cambridge, MA: BBN Laboratories, Inc.

Reviews several emerging technologies for their applicability to embedded training. Technologies reviewed include computer-generated imagery (CGI), image storage and retrieval, speech synthesis, speech recognition, symbolic processing, and large-scale digital storage.

MATRIS Summary Report. (1989). San Diego, CA: Defense Technical Information Center.

Summaries of ongoing research projects in embedded training. Based on a MATRIS database retrieval conducted on 27 November 1989, using "Embedded Training" as a descriptor.

McNeley, T.L., Hayes, D.R., Eckel, J.S., Ramsey, L.A., Dobbins, F.W., & Freytag, K.A. (1988). *Follow-on embedded training evaluation demonstration* (Report No. 20PR215). Ft. Worth, TX: General Dynamics.

Identifies the basic training features that would provide a full combat spectrum of training needs acceptable to the user. Identifies, demonstrates, and evaluates the electronic combat environment for air-to-air and air-to-ground training, training feedback desired from the system, and design/cost impacts for implementing the system.

Munzer, R.K., & Lawrence, T.C. (1989). Embedded training system component Functionality. *Proceedings of the 11th Interservice-Industry Training Systems Conference* (pp. 259-266). Arlington, VA.: American Defense Preparedness Association.

Describes the components of an ET system which will maintain aircrew proficiency within the constraints of the operational environment. Identifies operational needs used to focus ET system design efforts; also describes a set of components which must be contained in the ET system in order to satisfy user needs.

Naval Sea Systems Command. (1988). *Embedded training handbook #1: Should the system include embedded training?* (Report No. ET-TR 836.02-3). Washington, DC: Naval Sea Systems Command.

Provides guidance for the collection of information needed to make a judgement about inclusion of ET in the very early stages of development of a system. Provides a "best estimate" as to whether ET should be planned as a part of the system. The areas covered in the report include relationship to system development, collecting and compiling the information, and making the decision.

Oberlin, M. (1988). Some considerations in implementing embedded training. *Human Factors Society Bulletin*, 31(4), 1-3.

Identifies variables to be considered when deciding the feasibility of implementing ET, including nature of training, training environment, and political, host equipment, and training task considerations.

O'Brien, L.H. & Hess, R. (1988a). *Embedded training concepts for tactical aircraft: Volume I. Executive summary (ASD-TR-86-5019). Wright-Patterson AFB, OH: Aeronautical Systems Division.*

Presents an overview of a concept study on the use of ET in emerging tactical aircraft. Includes results of training requirements analysis and recommendations.

O'Brien, L.H., & Hess, R. (1988b). *Embedded training concepts for tactical aircraft: Volume II. Training requirements* (ASD-TR-86-5019). Wright-Patterson AFB, OH: Aeronautical Systems Division.

Describes potential ET requirements and the ET concepts applicable to tactical aircraft. Develops functional concepts for ET systems for both the F-16 and ATF aircraft.

O'Brien, L.H., & Hess, R. (1988c). *Embedded training concepts for tactical aircraft: Volume III. Automated training projection methodologies* (ASD-TR-86-5019). Wright-Patterson AFB, OH: Aeronautical Systems Division.

Describes the development and use of two automated tools to provide early estimates of training requirements, plus cost and benefits, during concept development of new aircraft. The two tools included are the ET Quantification Methodology (ETQM) and the ET Projection Methodology (ETPM).

O'Brien, L.H., & Hess, R. (1988d). *Embedded training concepts for tactical aircraft: Volume IV. Appendices* (ASD-TR-86-5019). Wright-Patterson AFB, OH: Aeronautical Systems Division.

Includes the technical appendices to the concept study on the use of ET in emerging tactical aircraft, a review of training systems related to ET, technologies and concepts related to ET, discussion supporting material for both the F-16 and ATF concept identification, selected mission scenarios, functional task list, and impact of non-conventional concepts.

Rektorik, E. (1989). OBEWS: Simulation at Mach 1 on the deck-developing embedded training. *Proceedings of the 11th Interservice-Industry Training Systems Conference* (pp. 267-274). Arlington, VA: American Defense Preparedness Association.

Provides information about the requirements of the on-board electronic warfare simulator (OBEWS) on the F-16. Requirements include aspects of training requirements, system design, growth of the concurrency problem, and environmental constraints.

Roth, J.T. (1988). *Implementing embedded training: Volume 3 of 10. The role of ET in the training system concept* (ARI Research Product 88-13). Alexandria, VA: U.S. Army Research Institute.

Provides guidelines for making early estimates of training system requirements and potential allocation of a portion to ET.

Strasel, H.C., Dyer, F.N., Aldrich, R.E., & Burroughs, S.L. (1988). *Review of eight Army systems: Characteristics for embedded training* (ARI Research Note 88-14). Alexandria, VA: Army Research Institute.

Provides a review of four fielded and four developing Army systems. An analysis compares and contrasts the systems data on equipment, mission, personnel and task requirements, and current or proposed training systems. Provides insight into relationships between systems characteristics and ET questions.

Strasel, H.C., Dyer, F.N., Roth, J.T., Alderman, I.N., & Finley, D.L. (1988). *Implementing embedded training: Volume 2 of 10. Embedded training as a system alternative* (ARI Research Product 88-22). Alexandria, VA: U.S. Army Research Institute.

Provides guidelines for making a decision as to whether ET should be further considered as a potential training system.

Study Plan for Embedded Training. (1989). Joint Technical Coordinating Group for Training Systems and Devices (JTCG-TSD).

Describes coordinated Tri-Service initiatives to establish a systematic methodology and associated database specifying embedded training requirements in weapon system acquisition efforts. Dr. Don Peckham of the Army's PM-TRADE is the chairman of the Embedded Training Working Group.

Troop proficiency trainer/operator training instructions. (1986). (Tech. Manual TM 9-6920-600-14). Washington, DC: Headquarters, Department of the Army.

Assists tactical training officers in use of the embedded training subsystems on the Patriot Air Defense Guided Missile System.

Warm, R.E., Roth, J.T., Sullivan, G.K., & Bogner, M.S. (1987). *Tri-service review of existing system embedded training components.* Alexandria, VA: U.S. Army Research Institute.

Examines the characteristics of ET implementation in a selected set of nine (3 USAF, 3 Navy, 3 Army) systems which are currently operational. The report explores the manner in which ET components have been developed and employed. Provides lessons learned which may help in providing guidance for development of future ET components. The review includes selection of systems, data collection, site visits, analysis, and results.

Zahm, M.K., & Hammond, J.H. (1989). 89-OBT: Expanding the Navy's ASW/ASUW training capabilities using state-of-the-art stimulation techniques. *Proceedings of the 11th Interservice-Industry Training Systems Conference* (pp. 427-434). Arlington, VA: American Defense Preparedness Association.

Describes the major capabilities and features of the 89-OBT design, and types of individual and team training supported by it. Includes design features and capabilities, physical elements of instruction/operator interfaces, interfaces with tactical equipment, types of training currently supported, and completed and planned enhancements.

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